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Rangeland Watershed Water Budget and Grazing Cattle Waste Nutrient Cycling

Oklahoma Agricultural Experiment Station
Stillwater

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Robert S. Kerr Environmental Research Lab.
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RANGELAND WATERSHED WATER BUDGET AND GRAZING CATTLE WASTE NUTRIENT CYCLING

by

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This research project was designed to determine baseline data concerning the source, movement, concentration and factors affecting nonpoint pollutants in runoff from a representative 60-hectare, tallgrass prairie watershed grazed by cattle in North Central Oklahoma. Measurements were made to determine precipitation and runoff amounts and concentrations of sediment, nitrogen, phosphorus, potassium, BOD, COD and TOC. Concentrations of N, P, K, Ca and structural carbohydrates were determined in live and standing dead vegetation and dung collected periodically from different locations on the watershed. Stocking density and grazing pressure were calculated. Independent site factors were used in regression equations to predict plant species abundance, live and standing dead vegetation biomass, utilization and dung pat density and biomass.

The amount of nonpoint source pollution contributed to receiving waters by runoff from the watershed was comparable to that from tallgrass prairie watersheds in other parts of the United States and was minimal when compared to other nonpoint sources of pollution. Significant runoff occurred in every season, but spring was the season with the greatest potential runoff and potential pollution because precipitation and soil water content were greatest and ground cover was lowest at this time. Sediment was the most significant pollutant. Direct overland movement of dung into stream channels was minimal because standing vegetation and ground litter.

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FOREWORD

EPA is charged by Congress to protect the Nation's land, air and water systems. Under a mandate of national environmental laws focused on air and water quality, solid waste management and the control of toxic substances, pesticides, noise, and radiation, the Agency strives to formulate and implement actions which lead to a compatible balance between human activities and the ability of natural systems to support and nurture life. In partial response to these mandates, the Robert S. Kerr Environmental Research Laboratory, Ada, Oklahoma, is charged with the mission to manage research programs to investigate the nature, transport, fate, and management of pollutants in ground water and to develop and demonstrate technologies for treating wastewaters with soils and other natural systems; for controlling pollution from irrigated crop and animal production agricultural activities; for controlling pollution from petroleum refining and petrochemical industries; and for managing pollution resulting from combinations of industrial/industrial and industrial/municipal wastewaters.

This project was initiated to evaluate the effects of livestock pasturing in the tallgrass prairie regions of the United States on the quality of nonpoint surface runoff. The pasturing regime, more commonly practiced in the tallgrass prairie, was evaluated to determine the potential contribution to nonpoint source pollution. This information is useful in determining optimal practices which will lead to the development of Best Management Practices (BMPs).

Clinton W. Hall, Director
Robert S. Kerr Environmental
  Research Laboratory

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ABSTRACT

This research project was designed to determine baseline data concerning the source, movement, concentration and factors affecting nonpoint pollutants in runoff from a representative tallgrass prairie watershed grazed by cattle in North Central Oklahoma. A 60-hectare, tallgrass prairie watershed, moderately grazed yearlong by beef cows and calves was instrumented to determine precipitation and runoff amounts and concentrations of sediment, nitrogen, phosphorus, potassium, BOD, COD and TOC. Soil types, range sites and topography were surveyed, mapped and described. Soil water content, live and standing dead vegetation biomass, dung pat density, ground cover and herbage utilization were determined at 29 locations on the watershed periodically from April 76 through October 78.

Concentrations of N, P, K, Ca and structural carbohydrates were determined in live and standing dead vegetation and dung collected periodically from different locations on the watershed. Stocking density and grazing pressure were calculated. Independent site factors were used in regression equations to predict plant species abundance, live and standing dead vegetation biomass, utilization and dung pat density and biomass. Changes in dung chemical composition over time were determined for dung deposited during different seasons and in place for different periods of time.

The amount of nonpoint source pollution contributed to receiving waters by runoff from the watershed was comparable to that from tallgrass prairie watersheds in other parts of the United States and was minimal when compared to other nonpoint sources of pollution, such as cropland and fertilized pastures. Significant runoff occurred in every season, but spring was the season with the greatest potential runoff and potential pollution because precipitation and soil water content were greatest and ground cover was lowest at this time. Sediment was the most significant pollutant and was contributed by watershed areas with no ground cover, such as cattle trails leading into drainageways and the sides of drainageway channels. Direct overland movement of dung into stream channels was minimal because standing vegetation and ground litter on the lower slope positions acted as a filter.

Plant transpiration rapidly depleted soil water between mid May and mid July, especially in the upper 35-cm of the soil profile. This drawdown reduced the probability of runoff from all precipitation events except intense thunderstorms during the summer and fall. Tallgrasses, standing vegetation and ground cover were much greater on loamy prairie range sites on lower slope positions, whereas dung density and biomass were greater on the upland, more xeric, shallow prairie sites. Areas selected by cattle for bedgrounds and resting areas had a much greater influence on dung distribution than did areas selected for grazing. Nutrient concentrations in dung decreased to a steady state level in less than six months in any season of deposition.

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SECTION 1

INTRODUCTION

As the demands on rangelands for meat, water and other products and uses become more intense, the need to understand the fundamental relationships in rangeland ecosystems becomes more critical. Grazing by herbivores and water production have historically coexisted on rangelands. They will continue to coexist as long as we choose to utilize meat from grazing animals and water from runoff and as long as rangeland managers have and use the knowledge necessary to make grazing and water production compatible.

Considerable research has been conducted in the last decade on animal waste pollution. Relatively little research has been or is being conducted on potential water pollution from rangeland watersheds grazed by livestock.

Most of the interest in animal waste pollution has centered around point sources of pollution (e.g., feedlots) or nonpoint sources, such as cropland or intensively managed pastureland (e.g., dairy cattle pastures). These areas, however, receive much greater amounts of animal wastes or fertilizer nutrients than do rangelands. Environmental factors and relationships on rangelands are also greatly different from those affecting feedlot, cropland or pastureland nutrient cycling.

The need for research on water budgets and nutrient inventories and cycling on rangeland is critical and immediate. Rangelands and forest-ranges, as defined by the Society for Range Management (1975) and USDA (1974a), could provide either a large area for animal waste disposal or be a potentially significant source of water pollution. The realization of a beneficial and safe land use instead of a detrimental consequence of natural herbivore grazing depends largely on the capacity of different rangelands to receive and hold animal wastes without exceeding the acceptable level of pollutants in water runoff.

There are 416 million hectares of rangeland and forest-range or about 54% of the total land area in the 48 contiguous states (USDA 1974a). About 338 million hectares of range are grazed by livestock. The plains grasslands account for about 21% of all range and 62% of all U.S. grassland.

The emphasis on increasing red meat production and livestock numbers on rangelands is increasing rapidly (USDA 1974a). The relatively high price of grain and increased foreign demand for grain as human food have caused a greater interest in producing more forage-fed beef. The efficiency of conversion of solar energy by rangeland forage to red meat is much higher than that from other sources of livestock feed (Cook 1977). Much of the additional forage required for forage-fed beef will come from rangeland, and its efficient production will require a greater understanding of range ecosystems.

In much of the Southern Great Plains it is not uncommon for rangelands to be seasonally overgrazed as cattle are concentrated on rangeland until small grain crops are ready for grazing in the fall. Nationally it is common for ranchers to rely on rangeland to produce maintenance forage when inadequate water, fertilizer or growing conditions significantly reduce the high forage production usually expected from intensively managed pasture and farm forages. Excess animals are frequently maintained on rangeland during periods of low market prices because of the reluctance of livestock owners to sell their animals at an economic loss. Drought and market price fluctuations in the past, and no doubt in the future, will cause periodic long- or short-term periods of overgrazing. Even when rangeland is properly stocked, livestock tend to concentrate grazing and resting along watercourses unless grazing distribution practices are applied.

Because of the greater demands on rangeland to produce red meat while maintaining production of water of acceptable quality (P.L. 92-500) and the limited amount of information concerning potential water pollution from rangeland watersheds grazed by cattle, this study was designed to determine on a North Central Oklahoma rangeland watershed grazed by beef cattle (1) the source, transfer and transformation of potential pollutants, (2) the hydrologic and meteorologic parameters necessary to establish the water budget and movement of selected nutrients, (3) effects of environmental conditions on the rate of degradation of grazing cattle dung, and (4) effects of cattle waste concentration, chemical composition and distribution on levels of nutrients in soils.

SECTION 2

CONCLUSIONS

The amount of nonpoint source pollution contributed to receiving waters by runoff from this watershed, representative of tallgrass prairie watersheds grazed by cattle in North Central Oklahoma, is comparable to that from tallgrass prairie watersheds in other parts of the United States and is minimal when compared to other nonpoint sources of pollution, such as cropland and fertilized pastures. Significant runoff can occur in any season, but the season with the greatest runoff and pollution potential is spring when precipitation is greatest and ground cover is at the lowest level.

Sediment is the most significant pollutant and is contributed primarily by watershed areas with no ground cover, such as cattle trails leading into drainageways and the sides of drainageway channels. The potential danger of pollution from chemical leaching from watershed vegetation is very low compared to that of sediment and dung movement into drainageways. Direct overland movement of dung into stream channels is minimal because standing vegetation and ground litter on the deeper soils of the lower slope positions adjacent to stream channels acts as a retardant and filter. Utilization of standing vegetation is also relatively light in areas adjacent to stream channels.

Soil water drawdown and recharge cycles were much more consistent all three years of the study than were precipitation amounts and distribution. Soil water content decreases from maximum to minimum within about 60 days (i.e., mid May to mid July) primarily due to transpiration of actively growing vegetation. Soil water content in the lower part of the soil profile is much more consistent than that in the upper part of the soil profile. Soil water content is greater in ungrazed areas where standing vegetation and plant ground litter are greater than in grazed areas. Soil water use rates are closely related to soil water availability and the amount of growing vegetation. As vegetation matures in late summer, soil water recharge begins regardless of precipitation insoak.

Peak vegetation production varied each year and occurred earliest (June) during the driest year. Accumulative production of the different plant species classes amounts to 25 to 30% more production than peak standing crop. Therefore accumulative production of rangeland vegetation should be used as a measure of total production rather than peak standing crop. Productivity of grazed vegetation is about as high as that of ungrazed vegetation. Abundance of different plant species is closely related to slope position, aspect, soil types, range sites, A horizon and total soil water content and grazing pressure. From 80 to 90% of the variation in LIVE and STANDING DEAD vegetation can be accounted for with regression equations and independent site factors. Large differences in plant species composition and biomass, ground cover, herbage utilization and dung distribution can be expected on the basis of range sites.

The average effective duration of dung biomass is about two years since the average dung biomass on the watershed is about twice that deposited annually by grazing cattle. Chemical concentrations of N, P, K and Ca in fresh dung decrease with time and appear to reach a steady state in about six to eight months. Dung decomposition is apparently affected more by fragmentation and decomposer activity than by leaching or chemical transformation. Decomposition appears to be slower on the xeric, shallow prairie range sites than on loamy prairie sites. Cattle site preference for bedgrounds and resting areas has a greater influence on dung distribution and potential pollution sources than does site preference for grazing. The effect of urine on potential pollution is insignificant because of rapid movement into the soil or volatilization of N-compounds into the air and the absence of perennial streams on the watershed.

SECTION 3

RECOMMENDATIONS

RESEARCH

Additional water quality research conducted in Central Oklahoma should be on this watershed in order to utilize the extensive data base concerning soils, vegetation, ground cover and cattle grazing behavior and to utilize the facilities in place for determining streamflow and collecting water samples. A less intensive study of longer duration (e.g., 10 years) should be continued to determine the seasonal and annual variation in water quality and nutrient contribution from a tallgrass prairie grazed by cattle. Additional research, in general, should be conducted on environmental and management factors affecting dung distribution, fragmentation and decomposition and on those practices which minimize deposition near drainageways and which speed decomposition and nutrient cycling. Specific studies should determine 1) effects of fertilization, burning, mowing, supplementation, insects, birds and soil characteristics on dung fragmentation and decomposition, 2) factors affecting seasonal chemical composition of dung from grazing animals, 3) vegetation-soil water relationships (i.e., infiltration and soil water use) for major range sites, 4) changes in dung pat weight over time (i.e., decay rate), 5) factors affecting cattle site preference for bedgrounds, resting areas and intensively grazed areas and 6) the optimum amount of vegetation needed to minimize dung and ground litter movement into drainageways.

MANAGEMENT

All grazing management plans should incoporporate grazing distribution and watershed management practices which minimize dung deposition and maximize standing vegetation and ground litter along drainageways. Saltgrounds and feeding areas should be located away from drainageways. Yearlong stocking rates which maintain good range condition should be determined and not exceeded. Intensive rotation or seasonal grazing systems which produce heavy grazing pressure along drainageways in late winter and early spring should be avoided. Normal cattle behavior and site preference should be determined. When practical, excessively grazed upland sites should be reserved for winter grazing in order to maintain ground cover and best utilize the relatively higher quality standing dead forage. Practices which encourage cattle to trail along contours rather than directly downslope and across stream channels should be implemented. Stream-crossing points where the soil and channel banks are least erodable should be made more attractive or accessible to cattle. Shade trees along ridgetops for summer resting areas and winter shelter, especially tallgrasses and windbreak trees, along south-facing slopes should be maintained.

SECTION 4

STUDY AREA

LOCATION

The study area is located at latitude 33°N, longitude 97°W about 16 km northwest of Stillwater, Oklahoma. Most of the watershed area is located in the NW¼, S32, T20N, R1E of the Indian Meridian. The remainder of the watershed is located in the southwest quarter of Section 32 and the eastern edge of Section 31 (Figure 1). It is accessible from Stillwater during dry weather by a direct route involving 13 km of paved roads and 6.5 km of graveled roads. During wet weather the watershed can be reached by a 32-km drive on paved roads.

The watershed is part of the area acquired by the Land Utilization Division of the Resettlement Administration when the Lake Carl Blackwell dam was constructed (Park 1937). In 1947, control of the watershed and much of the land around Lake Carl Blackwell was transferred to Oklahoma State University. Since that time the watershed area has been used as a research area for grazing by beef cattle.

The watershed has been seasonally grazed with cows and calves for many years prior to the study. Grazing continued during the study as before. The area is generally not grazed during the last two weeks of April and during the 75 days between 1 August and 15 October. The average grazing use for the watershed during the study period was 70 to 80 animal-unit-days/ha.

Dry cows are supplemented with about 1 kg of 41% protein cottonseed meal/hd/day from 15 October to 31 December when they are removed from the watershed. From late January to mid April cow/calf pairs are fed 2.7 kg of 20% protein soybeanmeal range cubes and 1.8 kg of prairie hay per pair per day. A dicalcium-phosphorus mineral supplement plus sodium chloride salt is provided free choice during all grazing periods.

The study area is part of the Lake Carl Blackwell watershed. Lake Carl Blackwell provides municipal water for Stillwater. Runoff from the study area flows into Lake Carl Blackwell, then into Stillwater Creek, Cimarron River, Arkansas River, Mississippi River and the Gulf of Mexico.

CLIMATE

Temperature

The climate of the area is continental with hot summers and moderate

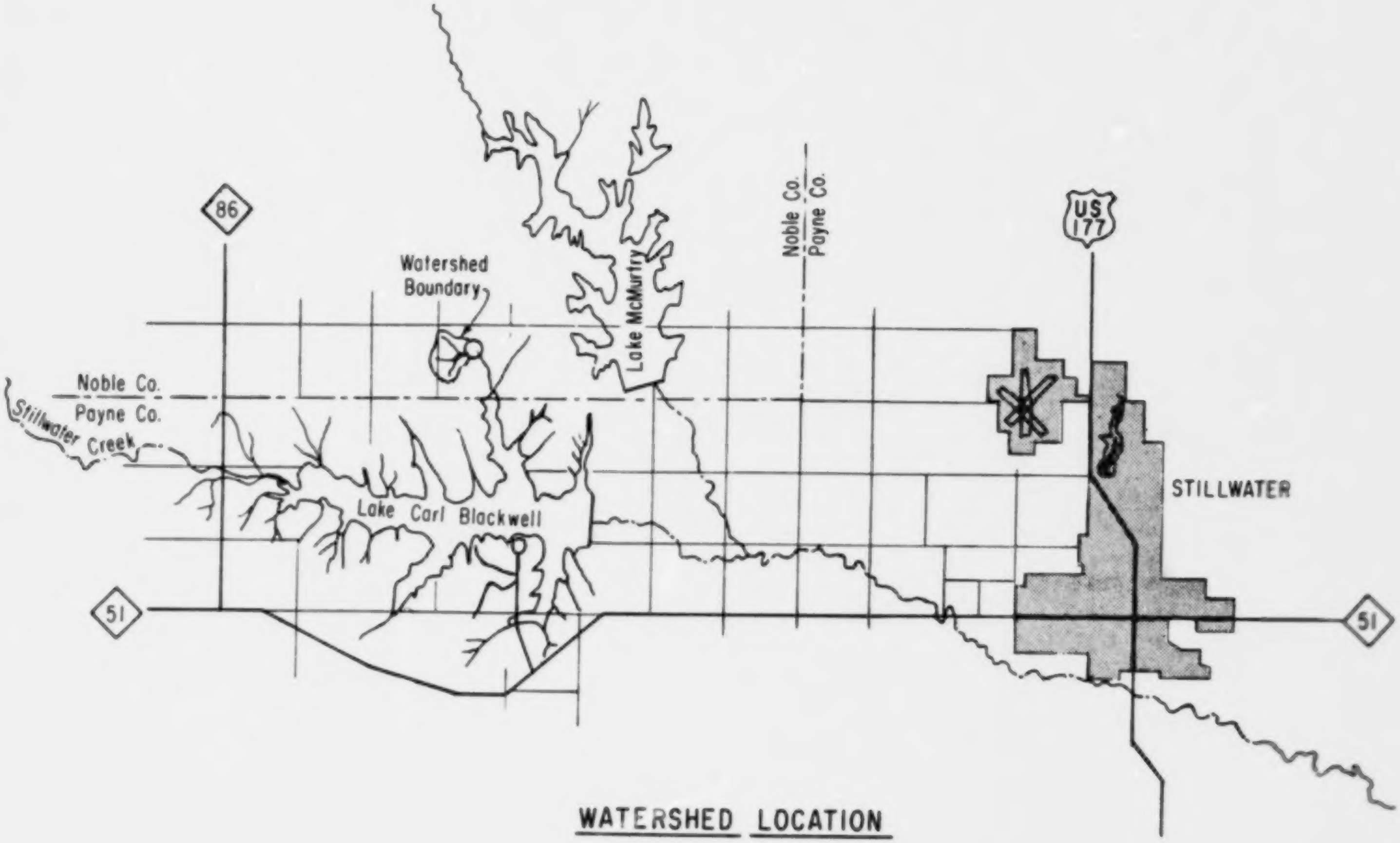
86
Watershed Boundary
Lake McMurtry
Noble Co.
Payne Co.
US 177
Noble Co.
Payne Co.
Stillwater Creek
Lake Carl Blackwell
STILLWATER
51
51
WATERSHED LOCATION

Figure 1. Environmental research watershed location and vicinity map.

winters. The average number of frost-free days is 206 from early April to late October or early November. The average absolute maximum temperature is 40 C or higher in June, July, August and September. The average absolute minimum temperature is -20 C or lower in December, January, February and March (Figure 2). July and August are the hottest months; January and February are the coldest months. The relationship between the monthly absolute maximum temperatures and absolute minimum temperatures is shown in Figure 3.

Warm (> 20 C) days are common during winter months, but cool (< 10 C) nights are rare during summer months. The average absolute maximum temperature ranges from 27 C in January to 45 C in July (range of 18 C), whereas the average absolute minimum temperature ranges from -26 C in January to 11 C in July (range of 37 C). Freezing depth in the soil rarely exceeds 25 cm.

It is uncommon for surface soil to remain frozen for more than two or three days during any one period except in January. In January surface soil is commonly frozen for periods of a week or longer. Significant snowmelt on frozen soil is uncommon.

Precipitation

Average annual precipitation is 820 ± 250 mm with about 75% occurring during the growing season. The average monthly precipitation ranges from about 120 mm in May to 30 mm in December, January and February (Figure 2). Precipitation amounts vary widely from year to year and from month to month. A climograph for the area is shown in Figure 4.

The relatively large rainfall amounts in May and early June are caused by warm fronts from the Gulf of Mexico to the southeast. Summer and fall rainfall is primarily from convectional thunderstorms. Cold fronts from the northwest in late October and November are generally dry. Precipitation from snowfall averages 25 mm per year. Snow cover on the ground averages about 10 days per year.

Relative humidity

The mean relative humidity varies from 62% in July and August to 71% in December and January. Diurnal fluctuations in relative humidity are wide during the summer. The maximum daily relative humidity is commonly 80 to 90% at sunrise during late spring and summer months. Several periods of relatively low relative humidity occur in late fall after cold fronts pass and high barometric pressure exists in the area.

Wind

The average daily windspeed varies from 215 to 230 km/day in April and March to about 125 km/day or less July through October (Figure 2). Winds are generally from the southeast in the spring and south or southwest in June through September. Cold fronts in late fall and winter are from the north and northwest. Calm days are rare during any part of the year.

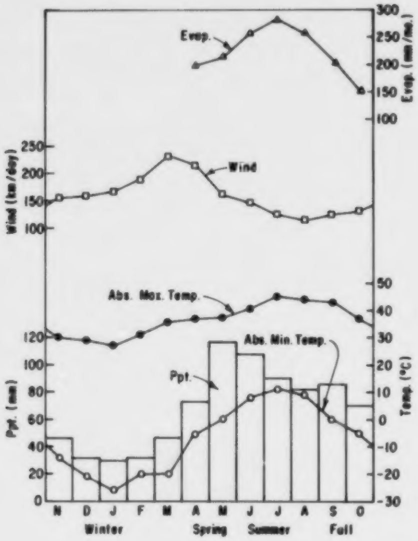

Figure 2. Long-term (1893-1980) climate for Stillwater, Oklahoma.

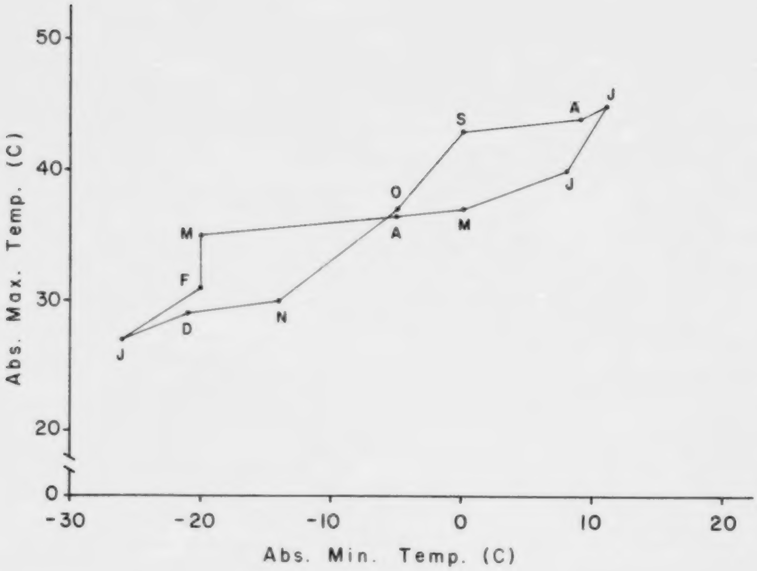

Figure 3. Average monthly absolute maximum and absolute temperatures (C), Stillwater, Oklahoma.

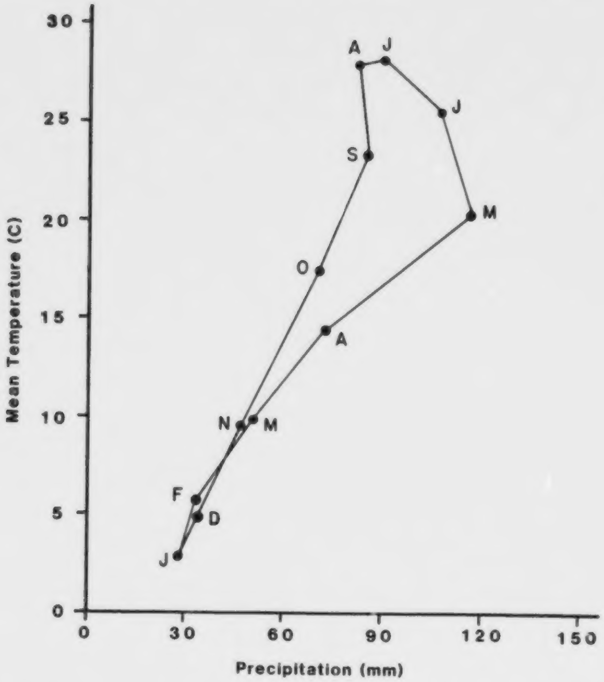

Figure 4. Climograph of average monthly temperature and average monthly precipitation for Stillwater, Oklahoma, 1893-1980.

Evaporation

Pan evaporation during the April through October growing season varies from 150 mm/mo. in October to 280 mm/mo. in July (Figure 2). The precipitation / potential evaporation ratio averages less than 1.0 every month of the year. During late spring and summer months, surface soils dry rapidly if the soil surface is bare or only partly covered with ground cover.

PHYSIOGRAPHY

Topography

The watershed is part of a prairie-woodland complex on undulating terrain (Figure 5). The elevation is about 300 m. The watershed lies in the upper reaches of the Lake Carl Blackwell watershed and is higher than much of the surrounding area. The general slope is to the east and to the south toward Lake Carl Blackwell and other components of the Stillwater Creek watershed. Most streams flow to the southeast in this area. There are very few perennial streams in the general area. There is no evidence the land has been plowed; however, there is a small area of terraces established about 1940-1950 to control erosion during an area reclamation project.

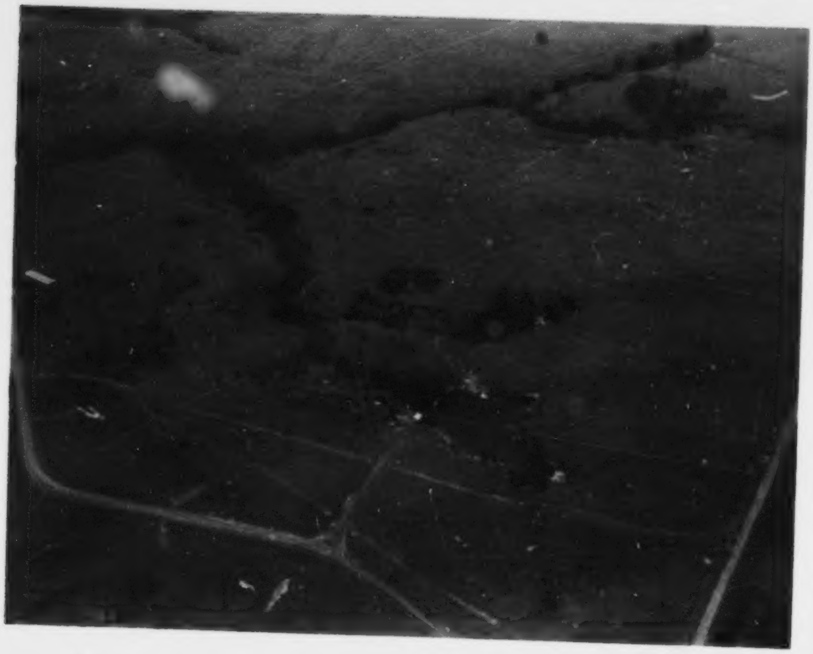

Figure 5. Aerial view of environmental research watershed, Noble County, Oklahoma.

The elevation of the watershed varies from 290 m at the main runoff-measuring weir to 318 m at the upper end. The topography is rolling with slopes averaging 3.6% on the upper 25% of the watershed and 5.3% on 55% of the area. The land adjacent to the drainageways has slopes averaging 9%. The weighted average slope for the entire watershed is 5.7%.

Topography and drainage patterns are shown in Figure 6. In addition to the contours, the map also shows the location of all permanent reference points for soil water and vegetation sampling, fenced exclosures, locations of rain gages, runoff measuring stations, and access roads. The watershed is composed of two principal drainageways which merge about 235 m upstream from the main weir. Drainage density is 8.9 km/km². The south drainageway drains 51% of the watershed. The length is 715 m and channel gradient is 2.0%. The north branch is shorter, 493 m in length, has a slightly flatter gradient, 1.5%, and drains 42% of the watershed. The remaining 7% of the watershed drains directly into the main drainageway, which has a 1.0% slope. As a result of the decreased slope the main channel has a pronounced sinuosity. Several bends about 100 m upstream from the main weir show evidence of mild bank erosion during periods of high flow. The drainage network characteristics as defined by the National Handbook of Recommended Methods of Water Data Acquisition (1978) are shown in Table 1.

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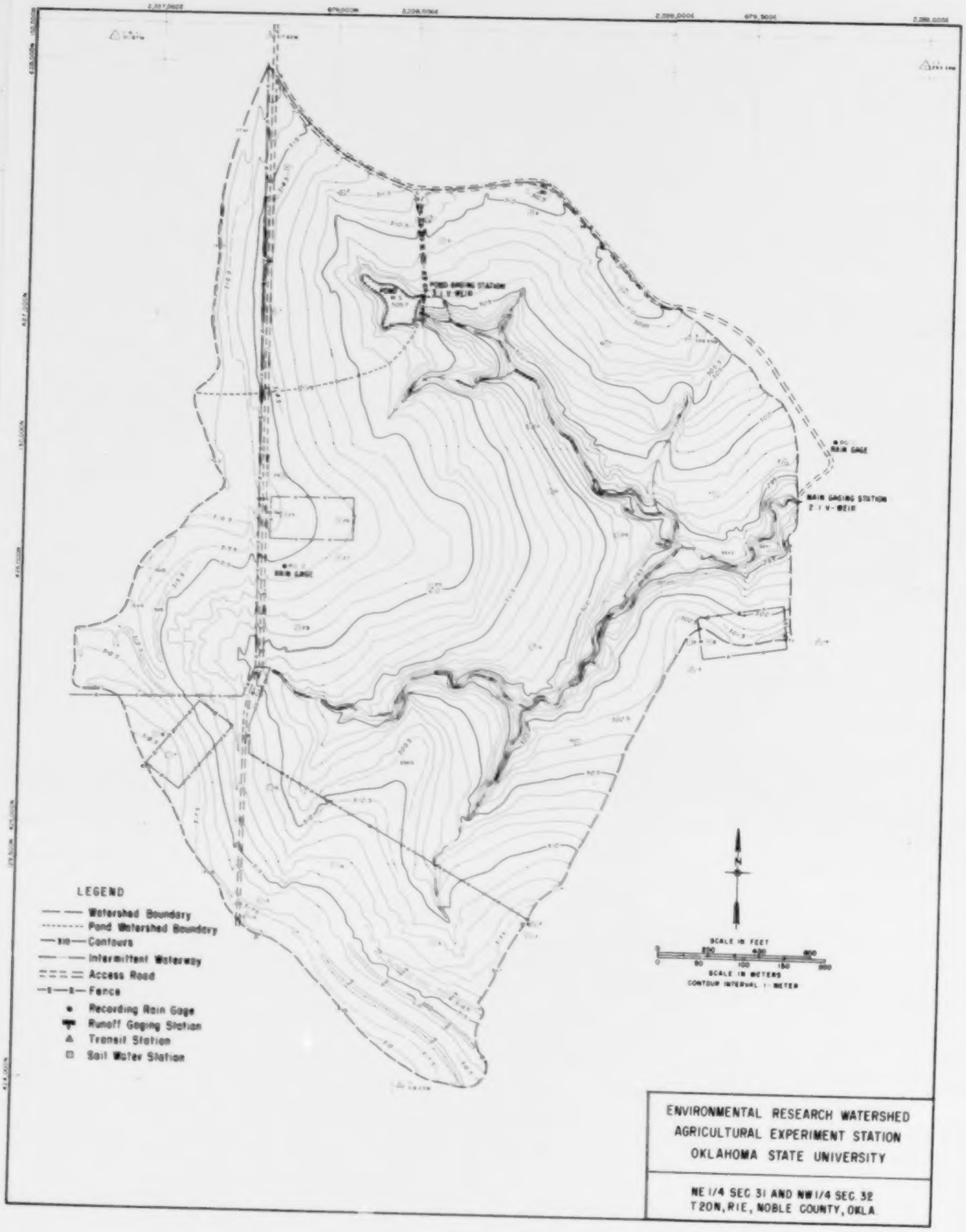
LEGEND
Watershed Boundary
Pond Watershed Boundary
Contours
Intermittent Waterway
Access Road
Fence
Recording Rain Gage
Runoff Gaging Station
Transit Station
Soil Water Station
POND GAGING STATION
RAIN GAGE
RAIN GAGING STATION 2:1 V-WEIR
N
SCALE IN FEET
SCALE IN METERS
CONTOUR INTERVAL 1 METER
ENVIRONMENTAL RESEARCH WATERSHED
AGRICULTURAL EXPERIMENT STATION
OKLAHOMA STATE UNIVERSITY
NE 1/4 SEC. 31 AND NW 1/4 SEC. 32
T20N, R1E, NOBLE COUNTY, OKLA.

Figure 6. Topographic map of experimental research watershed in North Central Oklahoma.

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TABLE 1. DRAINAGE NETWORK CHARACTERISTICS

Stream Measure	Stream Order		
	1	2	3
Number of streams	30	3	1
Bifurcation Ratio	10	3	-
Total Length, m	3205	1413	504
Mean Length, m	107	471	504

Total drainage area of the watershed is 57.7 ha. Land use includes 53.8 ha rangeland, 3.6 ha cultivated land planted each year to winter wheat, and a 0.3 ha stock water pond, located at the upper end of the north drainageway.

The pond has a drainage area of 6.9 ha, approximately 13% of the total watershed area. During periods of low runoff the pond water level is normally below spillway level causing all of the inflow into the pond to be retained and thereby reducing the total research watershed area by the amount of the pond drainage area. Runoff calculations were adjusted for the amount of runoff retained by the pond.

ACCESS ROADS

Access roads are essential for servicing instruments and caring for livestock, but they present a special problem for nonpoint source pollution studies because construction activities to improve the roads may artificially raise the level of pollution until vegetation is established in the roadside ditches. The environmental watershed has two access roads. The north-south road near the west boundary is a poorly drained existing field road. All of the runoff from this road flows directly into the main watershed drainageways. Therefore to eliminate the possibility of increasing the sediment load, this road was left in its original condition, except for the addition of small amounts of gravel. As a result, access to raingage RE2 was frequently difficult.

A new road was constructed along the northeast side of the watershed to provide access to rainfall and runoff recorders at the lower end of the watershed. To minimize the impact of the construction activities, the road was located on the watershed boundary, except for the hill beginning at the 310 m contour where it was located outside the watershed so runoff water draining from the road ditches would not be caught by the runoff sampler. Because of these precautions it is believed that there was little or no impact from construction activities on the quality of the water samples.

Geology

Oklahoma has rock formations ranging in age from most recent through Precambian. Periods of regional uplift, faulting and folding have alternated with periods when the area stood near or below sea level.

Formations generally dip to the west; however, the land surface elevation is higher and with less relief in the western part of the state than in the eastern part. Elevations vary from about 1400 m MSL in the Panhandle to less than 120 m MSL in the southeastern corner of the state along the Red River. All major streams drain to the southeast.

Central Oklahoma prairie soils, of which the study area is representative, developed from sedimentary shales, sandstones and clays. These materials are often bedded with horizontal strata composed of layers of varying texture. The clays and shales are generally well supplied with bases. In the study area sandstone outcrops are common and are readily apparent because of shrubs and trees on fractured sandstone or sparse, xeric herbaceous vegetation on unfractured outcrops.

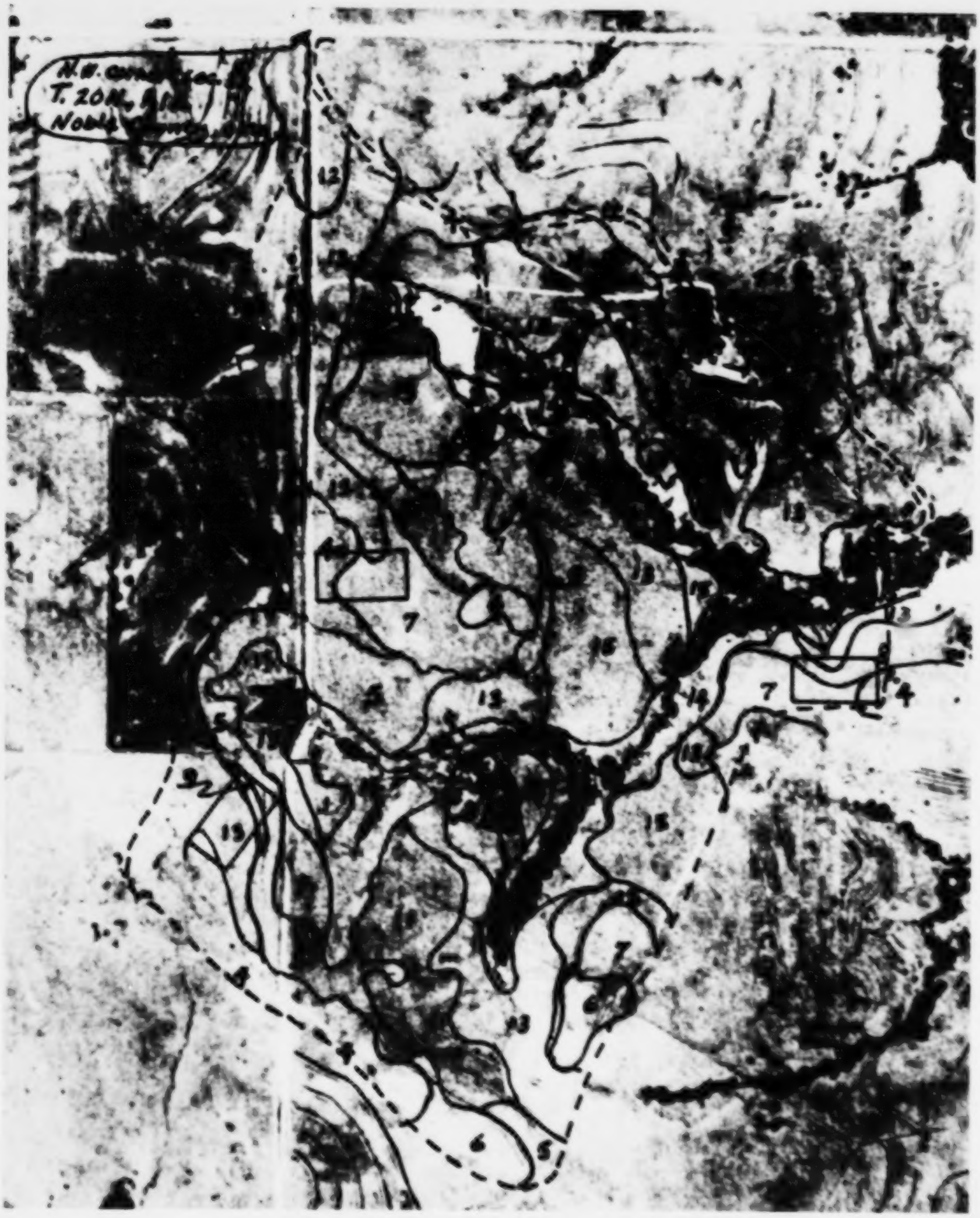
Soils

The distribution of soils is shown in Figure 7. A detailed description of the study area soils is in Appendix A. Soils of the surrounding area are described in the Noble County Soil Survey (Brensing and Talley 1956). In general soils of very-fine or fine-loamy, mixed thermic Vertic Haplustalfs occupy 70% of the watershed. The proportion of soil orders is 78% Alfisols, 16% Mollisols and 6% Inceptisols. All of the soils found in the study area are common to the general area and in about the same proportion as in the surrounding area.

Loamy soils developed under tallgrass prairie vegetation are most common. Soil fertility in the A horizon is high. A B_2 horizon is generally present. Soil water-holding capacity is good except on the limited area of coarse-textured soils.

VEGETATION

About 80 to 85% of the study area is grassland (Figure 8). Most of the plant species present in the area are those tallgrass prairie climax species described by Bruner (1934) and Carpenter (1940). Other existing grassland species common to lower successional stages of the tallgrass prairie have been described by Sims and Dwyer (1965). A survey conducted and vegetation map prepared by O. H. Brensing and E. C. Talley in 1940 reported the dominant vegetation to be the same climax species which were dominant when the study was initiated.


N.W. corner Sec.
T. 20N, R.1E
Noble County
12
13
7
16
14
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4
15
13
7
6
6
5

Figure 7. Soils map of experimental watershed in North Central Oklahoma. The description of each soil is in Appendix A.

Shrubs and trees are common along drainageways (Figure 9) and on shallow, coarse-textured soil overlying fractured sandstone (e.g., Darnell-Stephenville soil complex). Range sites include Loamy Prairie, Claypan Prairie, Shallow Prairie, Shallow Savannah and Sandy Savannah. These range sites are common throughout the surrounding area. Annual herbage production varies from 1700 kg/ha on Shallow Savannah sites to 3900 kg/ha on Loamy Prairie sites when the range is in good condition and under average growing conditions (USDA 1974b).

At the beginning of the study a qualitative range survey indicated the watershed was in high fair to low good range condition (J. Powell, personal observation). Both standing and ground litter were less than average because of relatively unfavorable growing conditions during the previous three growing seasons and excessive amounts of precipitation during the fall and winter periods of the same three previous years.

LAND USE

The study area has always been used for grazing, originally by buffalo and other native herbivores, and by cattle since the late 1800's. During the past 30 to 40 years, the area has been used by the Oklahoma State University Department of Animal Science for various range cow/calf beef production experiments. The stocking rate has been about 3.5 to 4.0 ha/animal-unit-year with one or two brief (15 to 30 days) periods of rest from grazing during the year. During the past 30 to 40 years the area has not been mowed for hay and has rarely burned. This history of use is representative for much of the prairie rangeland in Central Oklahoma.

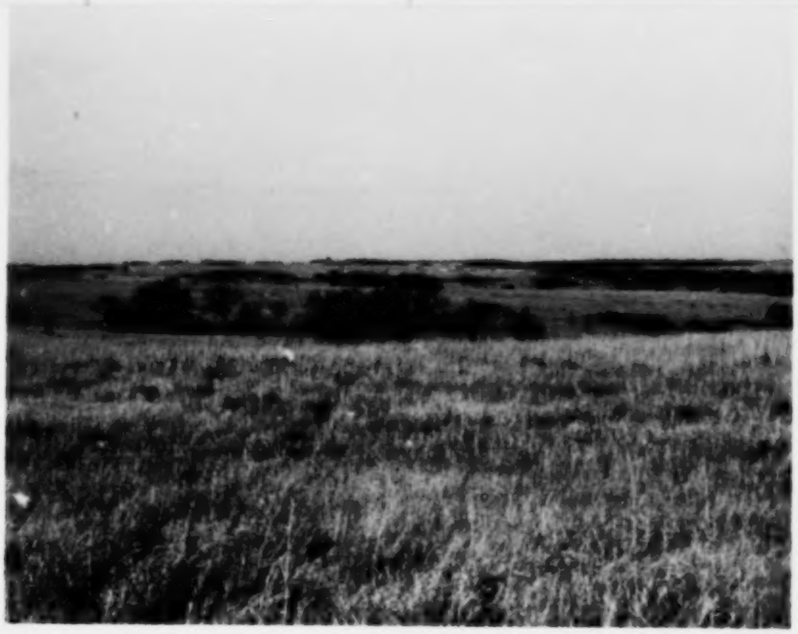

Figure 8. View of grassland aspect of experimental watershed in North Central Oklahoma.

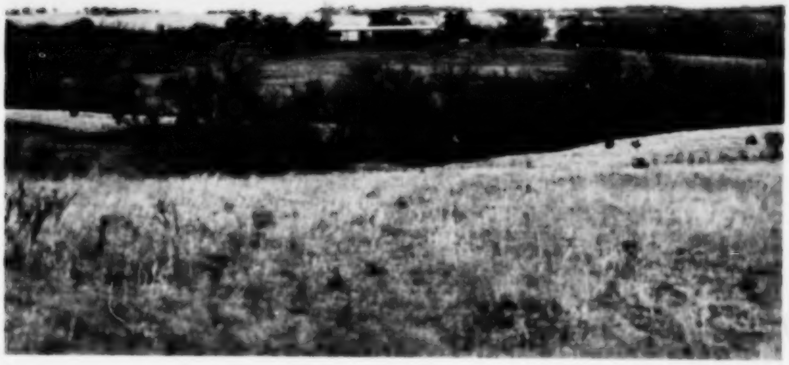

Figure 9. View of woody vegetation along drainageways in the experimental watershed in North Central Oklahoma.

SECTION 5

METHODS

WEATHER

Rainfall was measured at two locations selected to obtain adequate aerial distribution of precipitation over the watershed. The gage designated as RE-1 was located near the access road leading to the main weir. This gage was representative of rainfall that occurred on the lower end of the watershed. Gage RE-2 was on the upper end of the watershed about midway between the north and south boundaries. Both locations were in open areas that were free from interference by trees or buildings. A 3m by 3m fenced exclosure protected each gage from damage by cattle.

The rain gage charts were changed on a regular basis (Figure 10). The charts were removed immediately after each rainfall event and taken to the office for processing. The charts were read manually, using the "break-point" technique to determine periods of uniform rainfall intensity. The data were then transferred to computer cards.

Figure 10. Recording rain gage.

Instrumentation at the Class A weather station operated by the OSU Agronomy Department provided additional meteorological data useful for calculating a water budget. Instrumentation included a hygrothermograph for measuring and recording relative humidity and air temperatures; Eppley pyronometer and Lintronic integrator for measuring and recording solar radiation; and a class A evaporation pan and 3-cup anemometer for measuring daily evaporation and wind movement.

RUNOFF MEASUREMENT

Runoff from the environmental research watershed was measured by flow through a reinforced concrete triangular weir. The weir location was dictated by the requirement of a stable soil foundation that would not allow seepage around or below the structure and the further requirement that the channel gradient below the structure should have sufficient slope to avoid submergence of the weir by backwater. The site selected met both requirements, but the sinuosity of the channel directly upstream from the weir caused some preliminary concern. However, the elevation of the weir notch was set at such a height that the upstream channel was completely inundated at times of high flow rates, and sinuosity of the channel was not a problem. The location of the wier in relation to the approach and exit channels is shown in Figure 11.

Structural design of the weir was based on the standard designs recommended by the USDA SEA-AR Field Manual for Research in Agricultural Hydrology (rev 1979). The side slopes were 2:1 and the notch depth was 1.68 m (Figure 12). The top width of the weir notch was 6.72 m and the crest width was 40 cm. Figure 13 shows the plan and elevation construction drawings. Important features were a massive base to prevent shifting of the weir and a large stilling basin to prevent erosion downstream (Figure 14). Prior to construction, studies were made to determine if the exit channel had sufficient capacity to conduct from the structure without submerging the weir. The simulation verified that the weir operated with free fall at all times.

The weir was designed for a maximum discharge capacity of 11.45m^3/sec, which is equivalent to the expected runoff rate from a hydrologic event with a recurrence interval of 100 years. The head-discharge relations for the main weir were developed using procedures and coefficients developed by the USDA SEA-AR Water Conservation Structures Laboratory (1967). Field survey of the weir included profiling of the upstream and downstream edges of the weir crest. Discharge equations for each of five different head ranges and the rating table developed from these equations are shown in Appendix B. It should be noted that although English units were used in the equations, the final values of runoff rate and amount were later converted to metric units.

A continuous record of water stage at the weir was recorded by a standard FW-1 water level recorder mounted in an instrument shelter at the top of a 61-cm diameter corrugated metal still well. The recorder was equipped with a battery-powered chart drive and was operated at a chart speed of one revolution per 12 hours. A supplemental staff gage was located 3 m upstream from the weir to assure that the water level recorder was properly zeroed at all times.

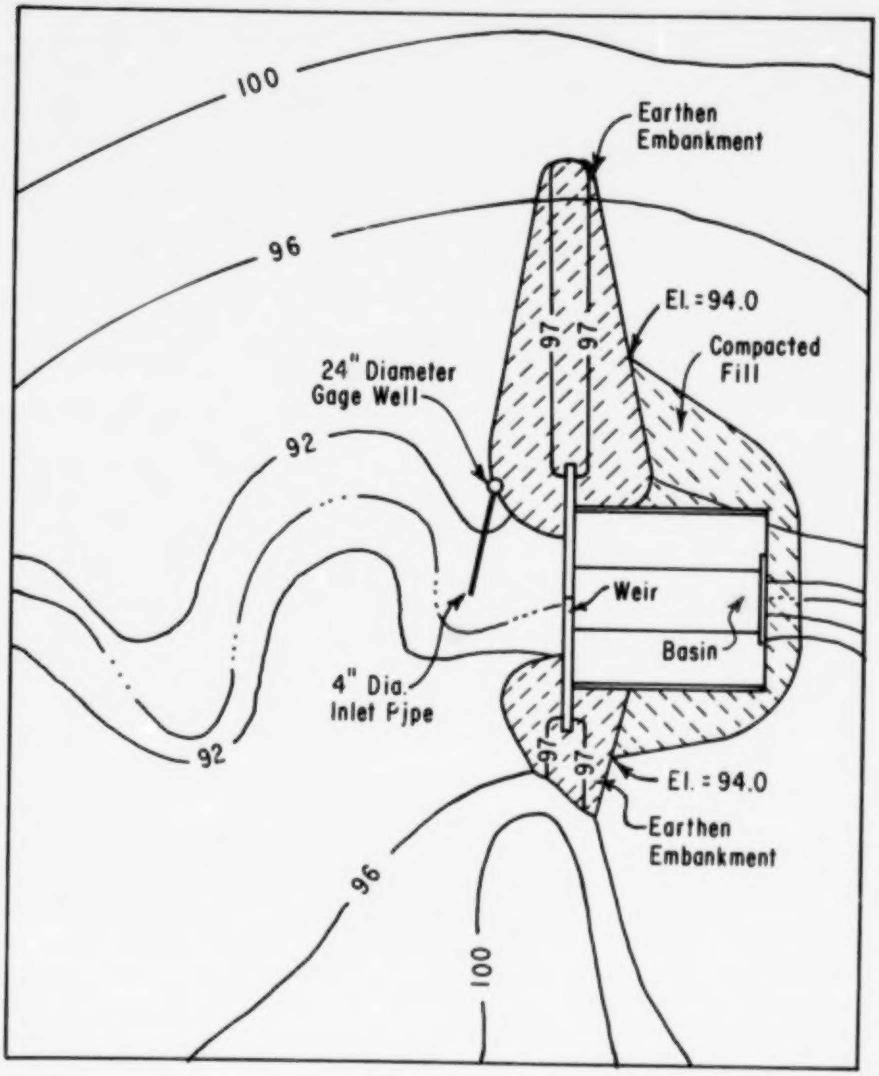
100
Earthen Embankment
96
97
97
El. = 94.0
Compacted Fill
24" Diameter Gage Well
92
Weir
Basin
4" Dia. Inlet Pipe
92
97
97
El. = 94.0
Earthen Embankment
96
100

Figure 11. Site location of main weir.

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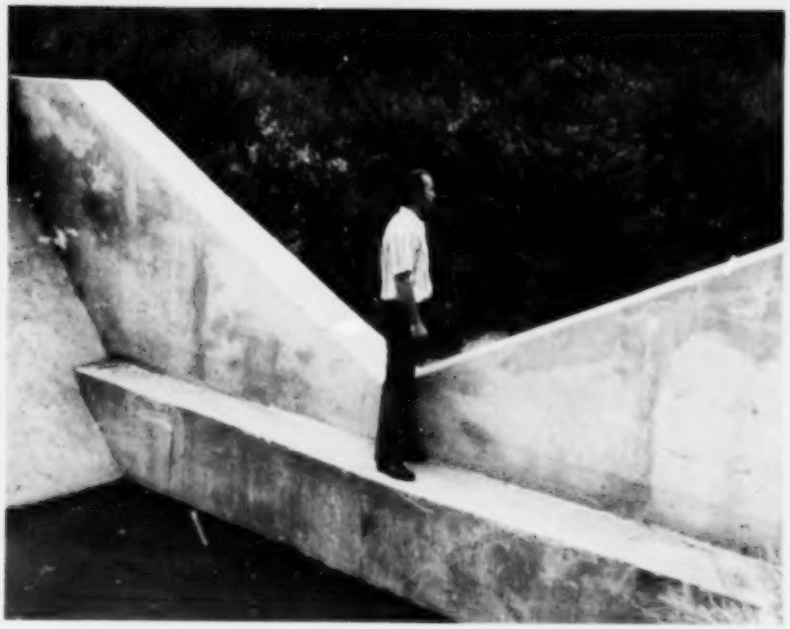


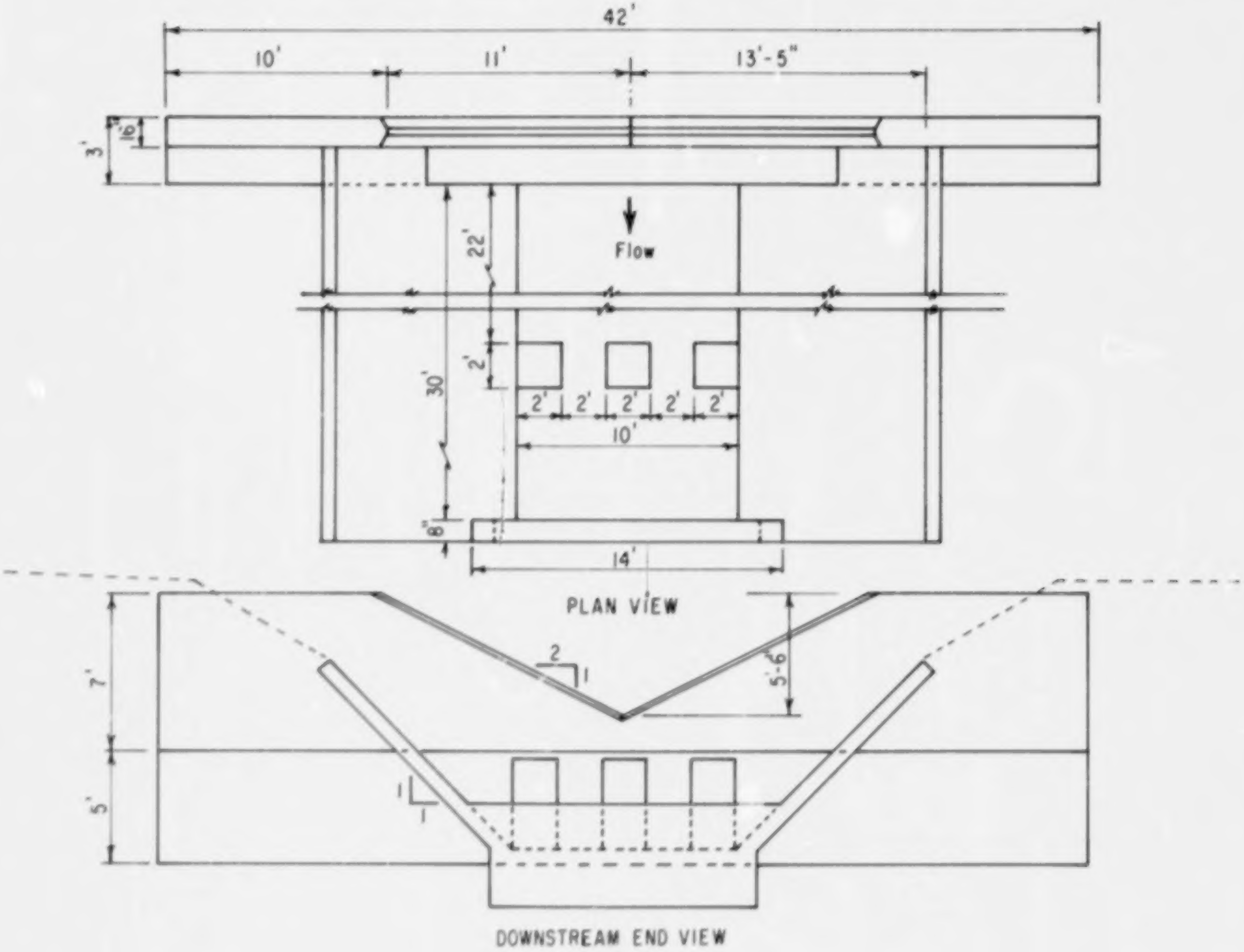
Figure 12. View of V-notch of watershed main weir.

Runoff through the pond spillway was measured by a reinforced concrete V-notch weir with 3:1 side slopes and a crest width of 40 cm (Figure 15). The maximum discharge capacity was 1.32 m^3/sec at a head of 61 cm. Head on the flow was recorded by an FW-1 water level recorder. A manually read staff gage was also set up to obtain the water surface elevation in the pond.

Runoff recorders were serviced at weekly intervals or more often as needed. As soon as possible after each runoff event the chart was replaced and taken to the office for analysis. The heads and associated times were read manually at appropriate break-point intervals and transferred to computer cards for analysis by the University computer. The output from the computer calculations included clock time and associated rates of runoff, rate of change of storage due to temporary pondage upstream from the weir, runoff per time interval, and accumulated runoff. The program also provided a flow duration analysis that listed the peak rates and maximum volumes of runoff for time intervals ranging from one hour to eight days.

WATER SAMPLE COLLECTION

A modified Chickasha sediment sampler described by Allen et al. (1976) was installed beside the main weir for collecting water samples for sediment and nutrient analysis (Figure 16). During runoff events the sampler was programmed to pump water through the intake line, and after thorough flushing


42'
10'
11'
13'-5"
3'
16"
Flow
22'
30'
8"
2'
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2'
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2'
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10'
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PLAN VIEW
2
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5'-6"
7'
5'
1
1
DOWNSTREAM END VIEW

Figure 13. Plan and elevation drawing of main weir.

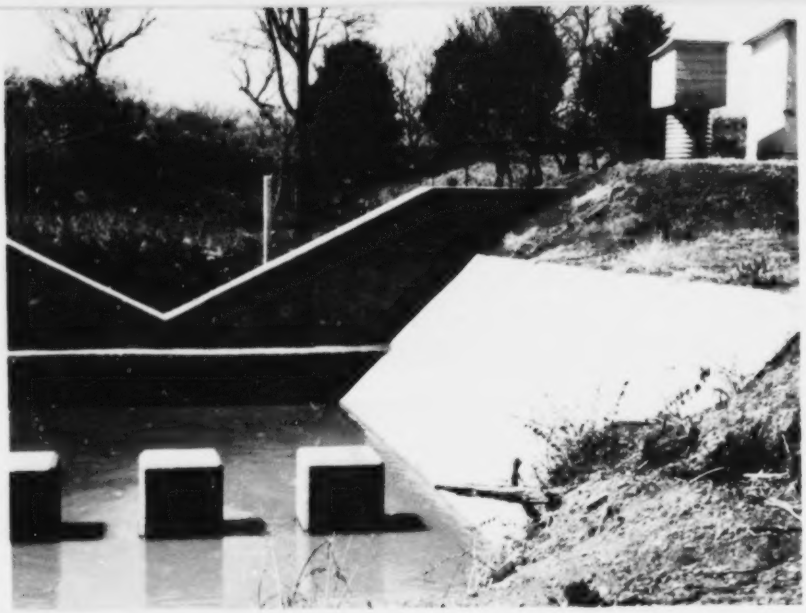

Figure 14. Downstream side of watershed main weir.

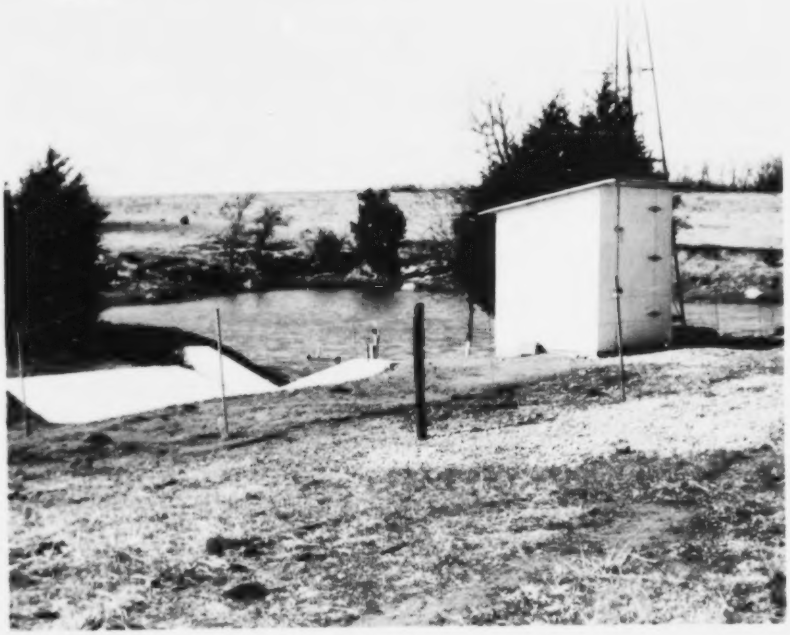

Figure 15. Watershed pond weir.

of the intake line, deliver the water to a 1000 ml plastic bottle. The sampler had the capacity to collect 24 samples at a sampling frequency that was either head-sensitive or time-sensitive. Both approaches were used at the environmental watershed. For the first several events the sampler was activated by a head-sensing device that caused samples to be taken at head increments of 7.6 cm on both rising and falling sides of the hydrograph. Because this method did not obtain enough samples from small runoff events, an electronic timer was installed which permitted most samples to be taken at intervals of 8 - 10 minutes. The time of sampler operation was noted automatically by a "tic" mark on the runoff recorder chart.

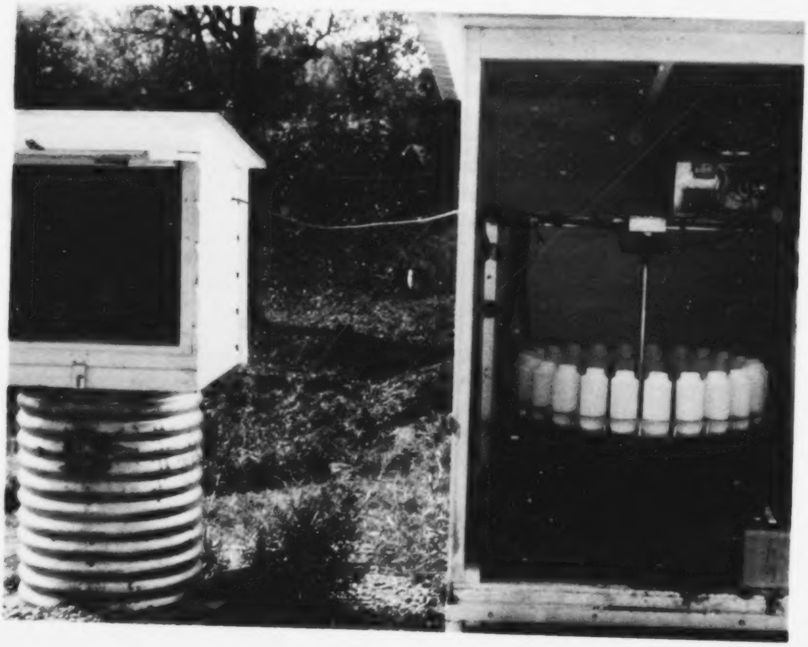

Figure 16. Head gage (left) and runoff samples (right).

WATER SAMPLE HANDLING AND ANALYSES

All samples were collected within 12 hours and stored at 4 C, or frozen until they could be analyzed. Because some types of analyses (e.g., BOD and COD), required a larger quantity of water, it was necessary to combine two or more successive field samples to obtain a composite sample large enough for analysis. On several occasions, BOD tests could not be made because the runoff event occurred on week-ends or holidays when laboratory personnel were not available to process the samples within the specified maximum holding time.

Water quality analyses were made according to procedures outlined in EPA Standard Methods (1974) for sediment, nitrogen, phosphorus, potassium, COD, BOD and TOC. Water analysis was contracted to the following laboratories: OSU Department of Agronomy Soil and Water Testing Laboratory; OSU Animal Sciences Department Testing Laboratory; OSU Water Quality Research Laboratory (Dr. S. L. Burks, Director); and Toetz Water Analysis Laboratory. A brief summary of the procedures is outlined in Appendix C.

SOILS

Soon after the project started, we determined the Noble County Soil Survey (Brensing and Talley 1956) was not detailed enough for our needs and the information in the Survey was in need of updating. A preliminary soil survey of the watershed was completed in August, 1975. Using the preliminary study as a base, we found the soil association on the watershed to be much more complex than normally reported in soil surveys.

Consequently, we resurveyed the watershed soils using a sampling location grid of 30 m by 60 m. The field work and mapping of soil units were completed by December 1975.

After the proportion and distribution of the various soils were determined, 29 permanent sampling locations were arbitrarily selected for soil and vegetation sampling. The number and distribution of locations provided a range in site conditions for regression analyses and replications on the major soil types in proportion to their percentage of occurrence over the watershed.

SOIL WATER

At each location, a neutron probe access tube was driven into the soil to the maximum depth possible. Access tube depths ranged from 22 to 137 cm which, at most locations, coincided with solum thickness. Soil water content at the 10-, 20-, 30-, 40-, 50-, 70-, 90-, and 110-cm depths depending on solum thickness, were determined with a portable neutron-scattering moisture meter (Stone et al., 1955) (Figure 17). Access tube installation was completed in March, 1976.

Soil water determinations were made at least monthly and often weekly depending on rainfall events and drying conditions (Figure 18). Because of the time required to determine soil water content at all 29 locations, soil water content was frequently determined for only seven locations. A regression equation was developed whereby the average soil water amount (cm) for all 29 locations was predicted on the basis of the data from the seven locations.

Soil water content (%) was determined at each of the depths in an access tube and then multiplied by a weighting factor. The weighting factors were used to compensate for unequal distances between depths of neutron probe readings. Percent soil water at each depth was multiplied by the appropriate

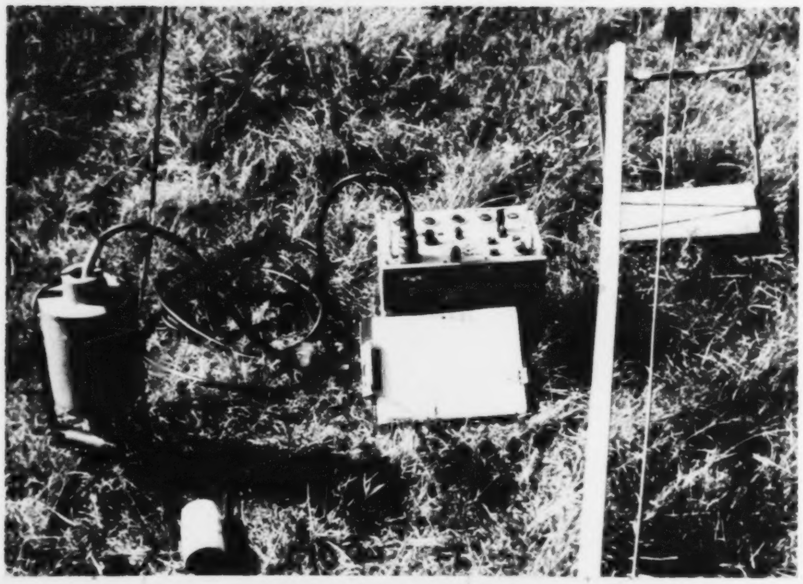

Figure 17. Equipment used to determine soil water content.

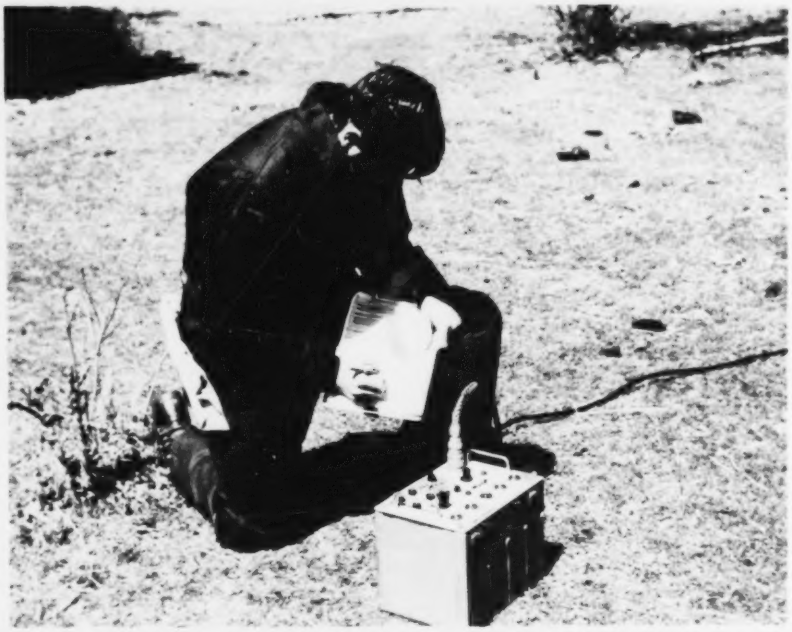

Figure 18. Recording neutron counts for soil water determination.

weighting factor as follows: 10-cm X (15-0), 20-cm X (25-15), 30-cm (35-25), 40-cm X (45-35), 50-cm X (60-45), 70-cm X (80-60), 90-cm X (100-80) and 110-cm X (120-100). The sum of these products for the determination depths at each location was used as a measure of total soil water (cm) per profile.

The coefficient of determination (R^2) using data from seven locations to predict total soil profile water for the average of all 29 locations was 0.93. The seven locations yielding the greatest coefficient of variation were selected. Seven locations were used because that number of locations could be sampled in a half-day period including driving time to and from the watershed to Stillwater.

Soil cores of 5-cm diameter were taken to the maximum depth possible with a hydraulic soil core probe mounted on a pickup truck. Cores were used to determine a soil profile description and horizon texture at each location.

Composite samples of soil from the A horizon at each location were collected, oven-dried at 105 C and analyzed by the OSU Department of Agronomy Soil & Water Testing Laboratory for pH, organic matter, phosphate, potash, calcium, magnesium, sodium, and iron contents. Total and ortho-phosphate, total and extractable iron, extractable potassium, calcium, magnesium and sodium, and NO_3-N and NH_4-N were determined at all locations at two different times in May, 1976. Total nitrogen was determined at all locations on eight different dates during the 1976 growing season. Organic matter content and pH at all locations were determined at the same times as was total nitrogen in 1976 and periodically in 1977 and 1978.

VEGETATION AND GROUND COVER

Herbaceous vegetation production and species composition were determined monthly at each of the 29 sampling areas using three, 0.5m^2 rectangular quadrats. Sampling locations were predetermined along radians from the access tube (Figure 19). Vegetation sampling was done between 5 m and 15 m from the access tube (Figure 20).

The double-sampling method (Wilm et al. 1944) was modified and used after a pre-sampling training period. LIVE weights of each species or species class, STANDING DEAD, and GROUND LITTER (including dung and woody material) were estimated for each sample using the weight-estimate method (Pechanec and Pickford 1937). Each kind of material and a dung sample were collected, bagged and weighed from one of the three samples.

Clipping was at ground level, and no sample areas were clipped more than once during the study. Total LIVE and STANDING DEAD was estimated, clipped, weighed, hand separated into LIVE and DEAD components in the laboratory, air-dried and reweighed. Percent dry matter and the estimation correction factor for the standing vegetation were determined from the clipped sample and used to adjust the estimated weights for all three samples at each location.

After air-drying the collected materials to a constant weight, each material was ground through a Wiley mill and 1-mm screen. Then Kjeldahl nitrogen, phosphorus, potassium and calcium contents were determined (AOAC 1970).

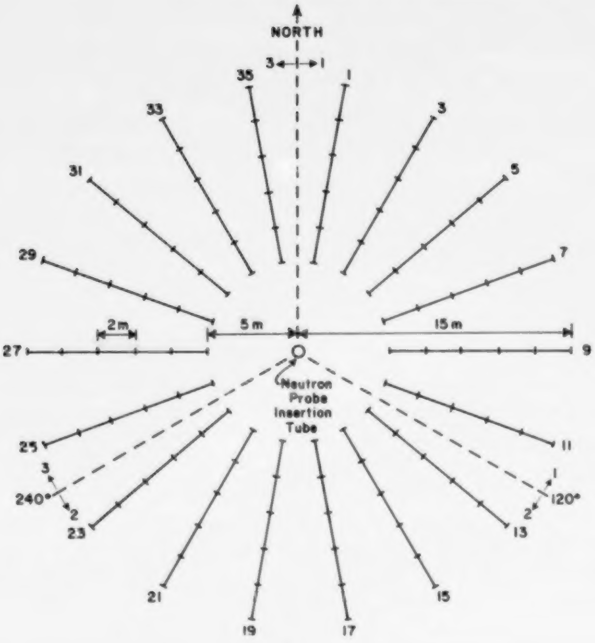
NORTH
3
1
35
1
3
33
5
31
29
7
2m
5m
15m
27
9
Neutron
Probe
Insertion
Tube
25
11
3
1
240°
120°
2
2
23
13
21
15
19
17

Figure 19. Schematic used to randomly select plot locations at each site.

Figure 20. Determining vegetation and ground cover.

The LIVE and STANDING DEAD plant samples were also analyzed for ash, acid-detergent fiber, acid-detergent lignin and cellulose (Van Soest and Wine 1968). In vivo dry matter digestibility of LIVE and STANDING DEAD plant samples was also determined using the nylon bag technique (Johnson 1969) in three rumen-fistulated steers grazing vegetation similar in species composition and stage of growth to that being digested (Figures 21, 22, 23 and 24).

During each monthly collection and at each clipped sample quadrat location, percent bare ground was estimated. Soil temperature at 5 cm deep, air temperature and relative humidity at 1 m above ground level and the corresponding time of day were recorded.

SITE FACTOR EFFECTS ON VEGETATION

In 1976 the effects of slope position, aspect and length on species frequency, ground cover, plant chemical composition and grazing intensity were studied. The watershed occupies parts of three different pastures. The moderately grazed watershed portion comprises about 80% of a 97-ha pasture. The lightly grazed watershed portion comprises about 20% of a 64-ha pasture. The small area along the western boundary includes wheat pasture and native prairie grazed from early November to mid March. The terms, moderate and light, merely indicate that the moderately grazed area receives heavier grazing pressure than the lightly grazed area. Since both pastures are stocked at a rate of 70 to 80 AUD/ha depending on growing conditions, the difference in grazing intensity is primarily due to a difference in grazing distribution. The lightly grazed portion lies at the greatest distance from water, corrals and feeding areas in that pasture.

Near the end of a winter grazing season in late February and early March, 1976, 20 transects of variable lengths were arbitrarily located on the watershed (Figure 25). Five transects were located in the lightly grazed portion and 15 in the moderately grazed portion of the watershed. Transect locations were selected to represent the various site and vegetation conditions present on the watershed. Most of the transects were placed parallel with the slope and most of the transects extended from the top or near the top of a ridge down to within 10 m of the stream channel breaks. However, adjustments in direction or length were made to insure that the upper, middle and lower slope sampling areas fell within a 10-m diameter stand of relatively uniform vegetation. Sampling areas were then selected at the upper end, middle and lower end of each transect.

At each sampling location, three, adjacent 0.5-m² quadrats were used to estimate and collect STANDING DEAD and GROUND LITTER biomass (Figure 26). Estimates of STANDING DEAD and of GROUND LITTER biomass in all three samples were made using the weight-estimate method. One of the samples was then systematically selected for clipping at ground level and herbage collection. Clipped samples were weighed in the field to derive an estimation correction factor and as continuous training for the estimators. The collected STANDING DEAD and GROUND LITTER samples were oven-dried at 50 to 60 C to a constant

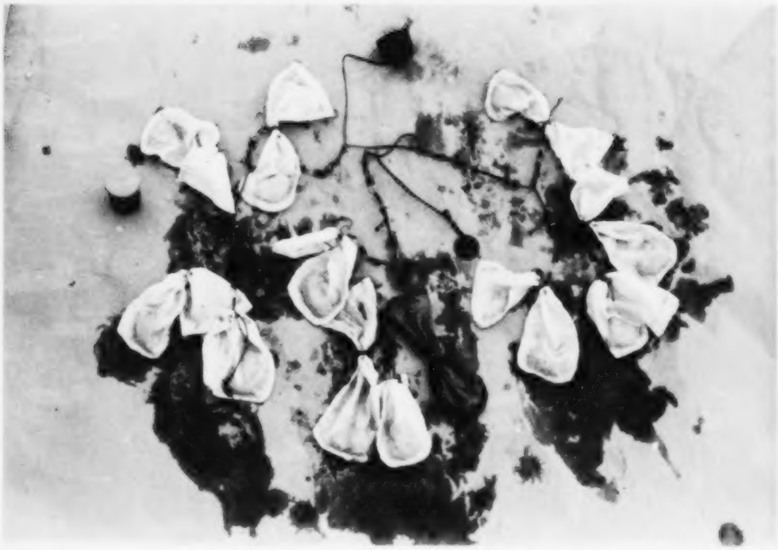

Figure 21. Nylon bags used to determine dry matter digestibility.

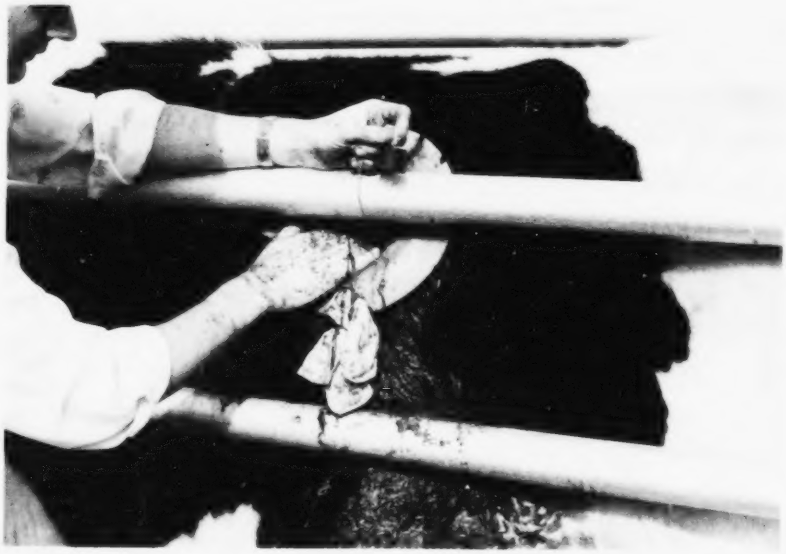

Figure 22. Inserting nylon bag set through canula.

TYPING GUIDE SHEET

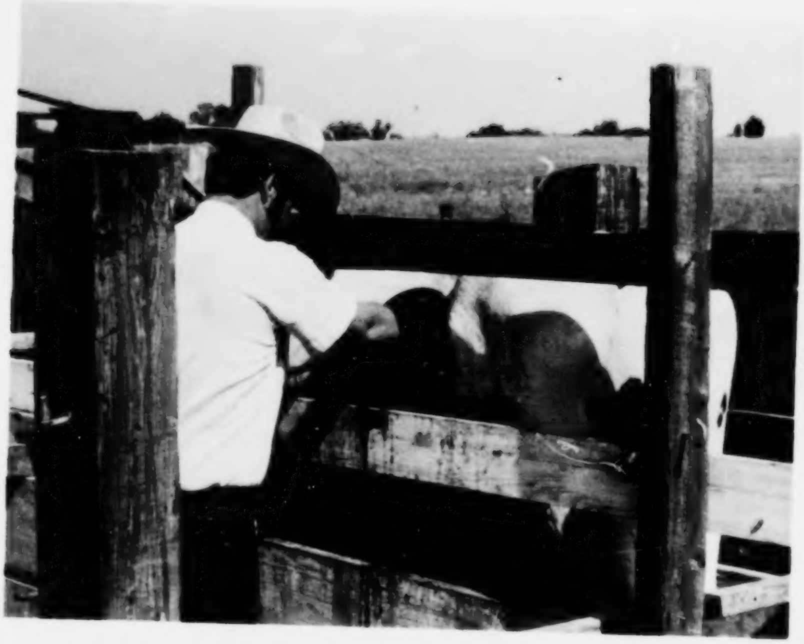

Figure 23. Renewing nylon bags after 48-hour digestion period.

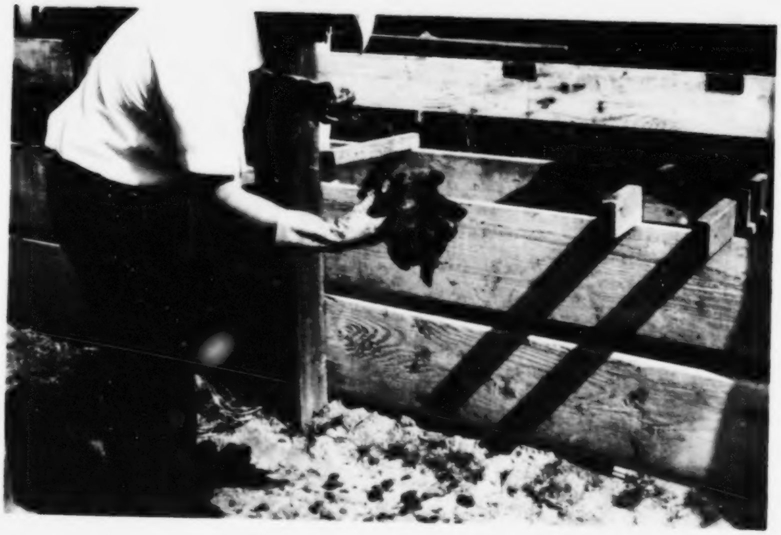

Figure 24. Nylon bags with digestion residue before washing.

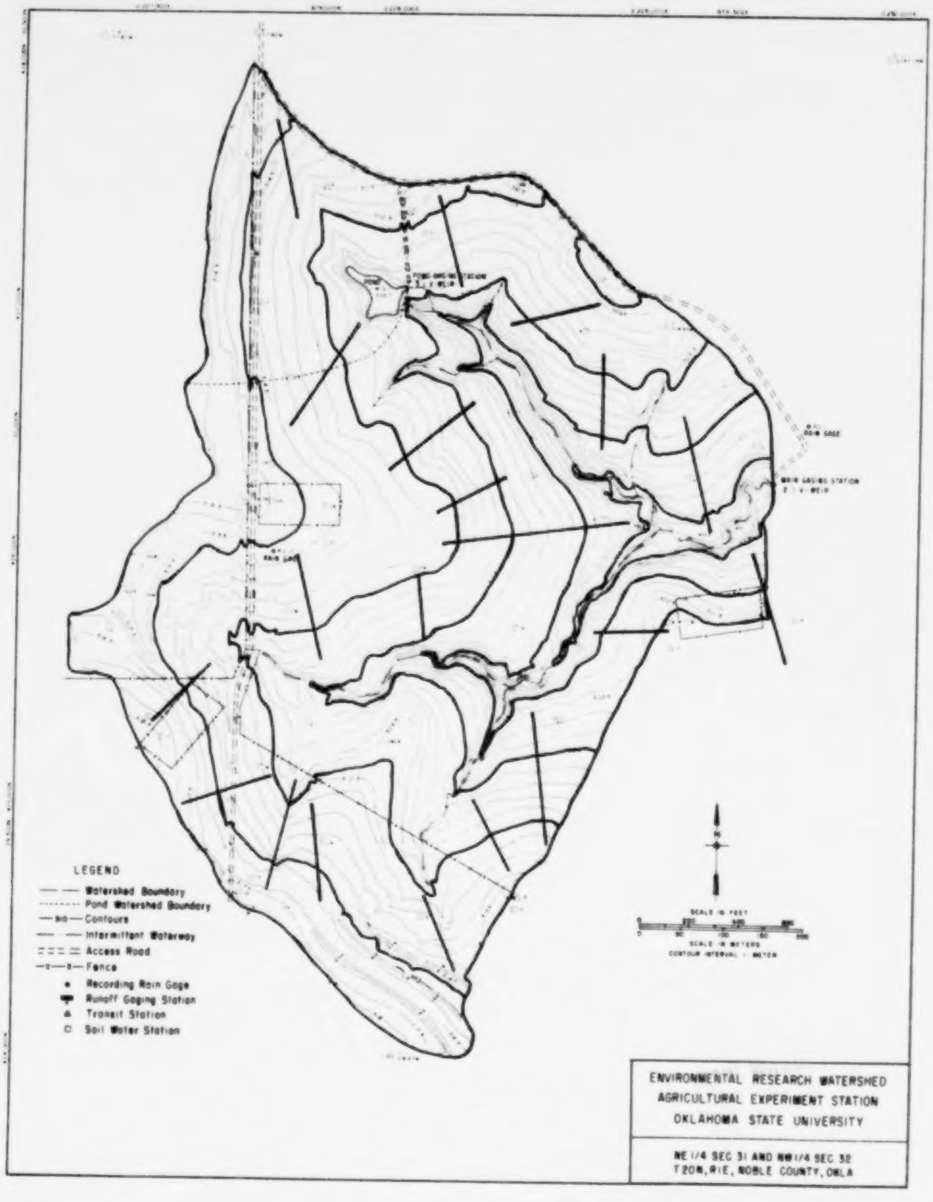
LEGEND
Watershed Boundary
Pond Watershed Boundary
Contours
Intermittent Waterway
Access Road
Fence
Recording Rain Gage
Runoff Gaging Station
Transit Station
Soil Water Station
Rain Gage
Main Gaging Station
Pond Gaging Station
SCALE IN FEET
SCALE IN METERS
CONTOUR INTERVAL 1 METER
N
ENVIRONMENTAL RESEARCH WATERSHED
AGRICULTURAL EXPERIMENT STATION
OKLAHOMA STATE UNIVERSITY
NE 1/4 SEC 31 AND NW 1/4 SEC 32
T20N, R1E, NOBLE COUNTY, OKLA

Figure 25. Location of 20 transects used to determine species frequency in relation to slope position, aspect and soil types.

weight, ground through a Wiley mill and analyzed for Kjeldahl nitrogen, phosphorus, potassium and calcium contents.

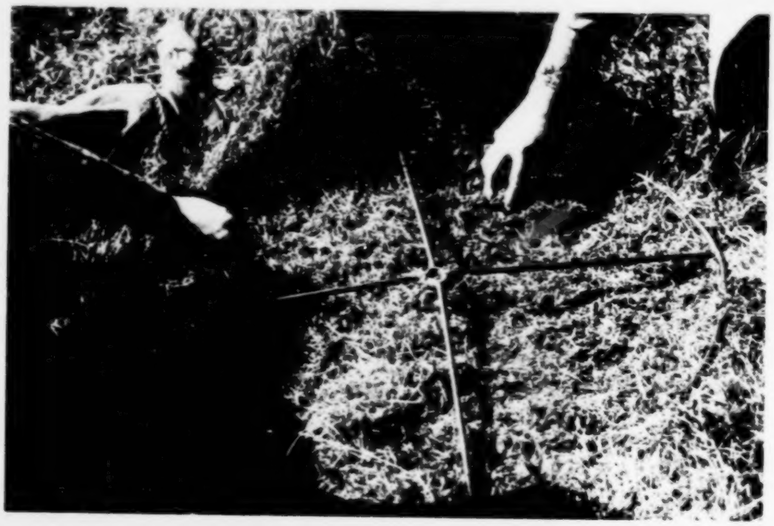

Figure 26. Collecting ground litter from one of three quadrats per transect.

Frequency of occurrence of all plant species was also determined at each location. The 0.5-m² rectangular frame consisted of two 0.25-m² subdivisions. The frame was placed four times about a center point at each slope position resulting in eight subsamples for each sampling location. Frequency of occurrence for a species was considered to be the percentage of the eight subsamples in which one or more plants of a particular species was found.

Concurrent with the biomass and frequency sampling, a soil sample was collected at each sampling location. After the A horizon thickness was determined with a soil tube, a 7.5-cm dia., steel cylinder was driven into the soil to obtain an A horizon soil core (Figure 27). The soil core was bagged and weighed in the field, oven-dried at 105 C to a constant weight, ground and analyzed for pH and organic matter, total nitrogen and extractable phosphorus, magnesium, potassium and calcium contents. The bulk density and soil water content of the A horizon soil core was also determined. Other site characteristics determined included aspect, percent slope, slope length, distance from ridge to sampling area, soil depth and micro-relief as flat, uniform slope, convex or concave.

All data were placed on magnetic tape and subjected to analysis of variance, multiple regression or correlation analyses using the Statistical Analysis System software program (Helwig and Council 1979). Differences in biomass weights and chemical composition and species frequency between slope positions in the lightly grazed area and in the moderately grazed area were tested by analysis of variance. Prediction equations for biomass and the

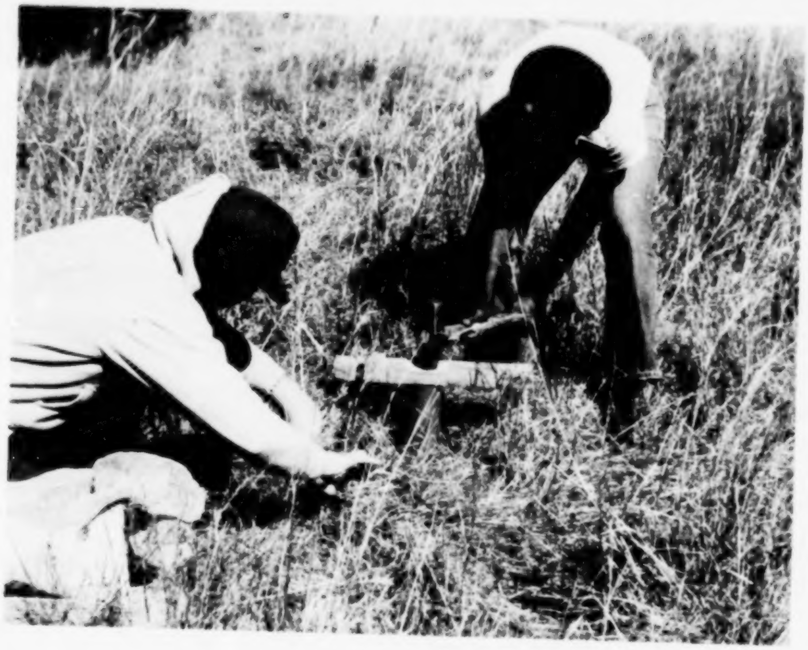

Figure 27. Collecting A horizon soil core for soil water and chemical composition determination.

frequency of occurrence of selected species were derived by using the SAS procedures, RSQUARE and REGR.

RSQUARE computes all possible regression equations for the dependent variable and specified number of independent variables. The coefficient of determination (R^2) and the independent variables in each equation are listed in the output. The two or three sets of independent variables accounting for the greatest percentage of variation in the dependent variable were selected and tested by REGR to determine the magnitude and level of probability for each regression coefficient. Only those regression equations with regression coefficients significant at the 10% or less level of probability were considered. Simple linear correlation analyses were also conducted to determine relationships between frequencies of different pairs of species, between different species frequencies and site factors and between biomass chemical components.

HERBAGE UTILIZATION BY LIVESTOCK

Three replicates of ungrazed conditions were established by constructing a permanent, 50 m X 100 m, cattle exclosure in February 1976 at each of three different locations along the upper boundary of the watershed. Barbed wire fencing was used to exclude cattle grazing, but permit grazing by rabbits and other native herbivores (Figure 28). Each of the exclosures was located so no runoff or overland flow material moved into the exclosed area.

Each exclosure was also placed in an area of what appeared to be different grazing intensity. The three intensities of grazing were arbitrarily labelled "Light", "Moderate" and "Heavy", although no preliminary quantitative data was collected before exclosure areas were chosen. An access tube and permanent sampling location was installed within each exclosure with a paired access tube located on the same soil type, but outside the exclosure in a grazed area.

In addition to the three permanent exclosures, a set of three temporary conical cages (Figure 29) were used at each of the 25 grazed locations to determine seasonal utilization. The cages were approximately 1 m in diameter and 1.5 m tall and constructed of woven wire, field fence. Each cage was staked in place to prevent movement by cattle.

About twice each year a 0.5-m^2 area under each cage was sampled to obtain the same kinds of information (e.g., soil temperature, LIVE and STANDING DEAD biomass) as obtained from the monthly samples on grazed areas. Each of the three cages was located along a radian in a predetermined manner so a grazed sample was adjacent to and served as a paired sample for each caged or ungrazed sample. After sampling caged areas, cages were moved to new sample areas along radians within the 5 to 15 m area at the same access tube location.

Herbage utilization (kg/ha) for the period since caged areas were previously sampled was calculated as the difference in herbage in caged areas minus that in grazed areas. Percent utilization was calculated as (100 X (caged herbage - grazed herbage residue))/(caged herbage). The procedures used to determine utilization using cages were generally similar to those described on p. 70 of Range Techniques (NAS-NRC 1962).

DUNG DEPOSITION AND DEGRADATION

A belt transect, 1-m wide, along both sides of each of three radians from 5 m out to 15 m from the access tube was established at each of the 25 grazed locations. All dung pats within the 2 m X 10 m belt transect area were counted. The number of dung pats per hectare was calculated for each location. A composite sample of dung from 5 to 10 pats was collected for chemical analyses and dry matter determinations.

In March 1977 all dung was removed by hand from the three, 0.5-ha exclosures, bagged, air-dried and weighed to determine dung biomass (kg/ha) in the three areas. Removing the dung also provided three dung-free, ungrazed areas.

In April and early May 1977 all dung pats were removed, air-dried and weighed from within the 30-m diameter circle around each of the 25 grazed sampling locations. This provided an estimate of dung biomass per hectare, a measure of dung distribution on the watershed, and reduced the large

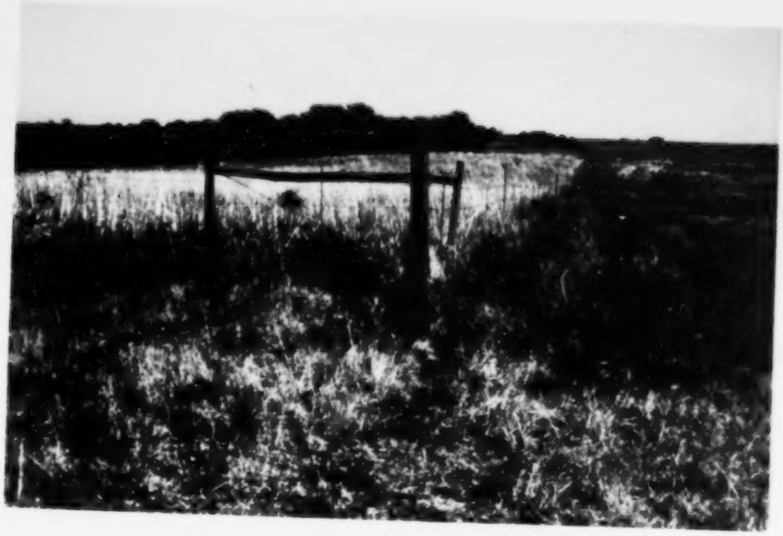

Figure 28. One of three exclosures constructed on watershed.

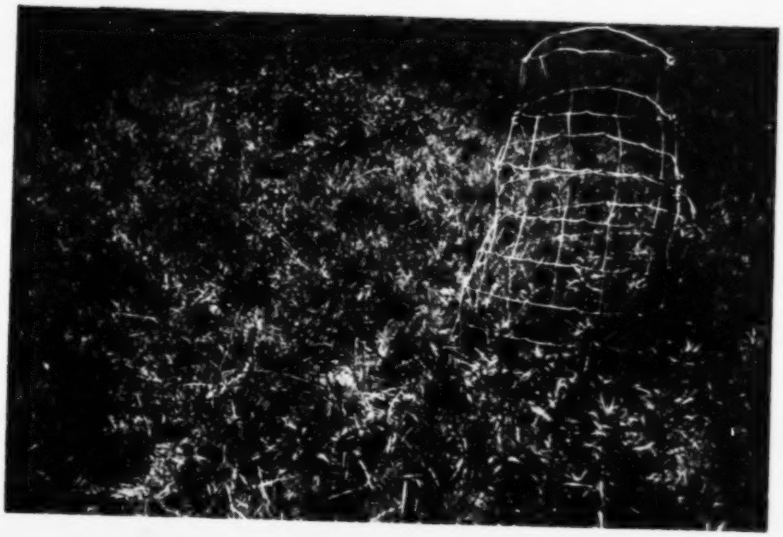

Figure 29. One of 75 movable cages used to determine herbage utilization by grazing cattle.

variation in GROUND LITTER estimates between samples. Continued counting of dung pats within the three, 2 m X 10 m belt transects at each location during each sampling period provided an estimate of the rate of dung pat accumulation and the time (months) necessary to re-establish an equilibrium between dung pat deposition and degradation.

Livestock grazing patterns on the watershed were determined periodically throughout the study period. The herd was followed for 4- to 5-hour periods on 10 occasions including four different seasons when dung pats were marked for a dung degradation study. In October 1977 the herd was observed continuously for 48 hours. From October 1977 until the end of the study the location of the herd and the time of day were noted each day the watershed was visited. All observations were mapped on a watershed map.

In July 1976, July and September 1977, and January and May 1978, in the middle of each month, the cattle herd was followed without interference as the herd moved about the watershed and adjacent parts of the pasture enclosing the watershed. The locations of 45 to 50 fresh dung pats were marked in place with aluminum markers and mapped on a map of the watershed (Figure 30).

Figure 30. Collecting dung pat to determine change in chemical composition after a known period of time after deposition.

During each occasion about half of the dung pats were dropped and marked in a 4-to 5-hour period in one morning with the remainder dropped and marked the following morning in about the same amount of time. Five dung pat samples were collected on the day of deposition during each of the five deposition periods. These included samples numbered 1, 7, 13, 19, and 25 in order of time of deposition. Five more samples were collected each collection period

30, 60, 120, 180 and 240 days after the day of deposition. Each time, every sixth sample was bagged and taken to the lab for chemical analyses. All dung samples were analyzed for total N, P, K and Ca. Dung samples collected in 1976 were also analyzed for acid-detergent fiber, acid-detergent lignin and cellulose.

SECTION 6

RESULTS AND DISCUSSION

WEATHER

Meteorological and Runoff Data

Meteorologic and runoff data for the environmental watershed are presented in Appendix D for each day during the period from April 1, 1976 through December 31, 1979. Maximum and minimum air temperature are self-explanatory. Relative humidity is the average of 24 hourly readings between 0000 and 2400 hours. Solar radiation is the total solar radiation during the 24-hour period. Wind travel is the total wind movement as recorded by a totalizing 3-cup anemometer installed with its axis 30 cm above the rim of the Class A evaporation pan according to standard operating procedures for Class A stations. Pan evaporation is the amount of evaporation from the Class A evaporation pan. Rainfall is the total precipitation, usually in the form of rainfall, measured by recording gages RE-1 and RE-2. Runoff is the total volume, expressed in depth uniformly distributed over the watershed, as calculated by integrating the hydrograph observed at the main weir at the outlet of the watershed.

Missing data in Appendix D indicate that either the instrument had not yet been installed, or that the instrument was inoperative on that date. For example, the recording hygrothermograph for measuring relative humidity was not put into service until September 1976. Also the Eppley pyronometer and Lintronic integrator for measuring solar radiation were not available until September 18, 1976. There are unavoidable gaps in the record due to malfunctions of both of these instruments. Also, evaporation pan data were available only during the frost-free months, usually from mid-April to mid-October, because the Class A pan was taken out of service during freezing conditions.

Temperature

Daily and mean monthly temperatures during the study period were within the range of average long-term temperatures for the Stillwater area. Vegetation growth is closely associated with extremes in temperature, especially the absolute minimum in January and the mean maximum in July (Powell et al. 1982). The degree of transpiration and subsequent soil water use are closely associated with the kind of vegetation present and the leaf area index. Therefore, the absolute maximum and absolute minimum temperatures per 7-day period during the study period are shown in Figure 31.

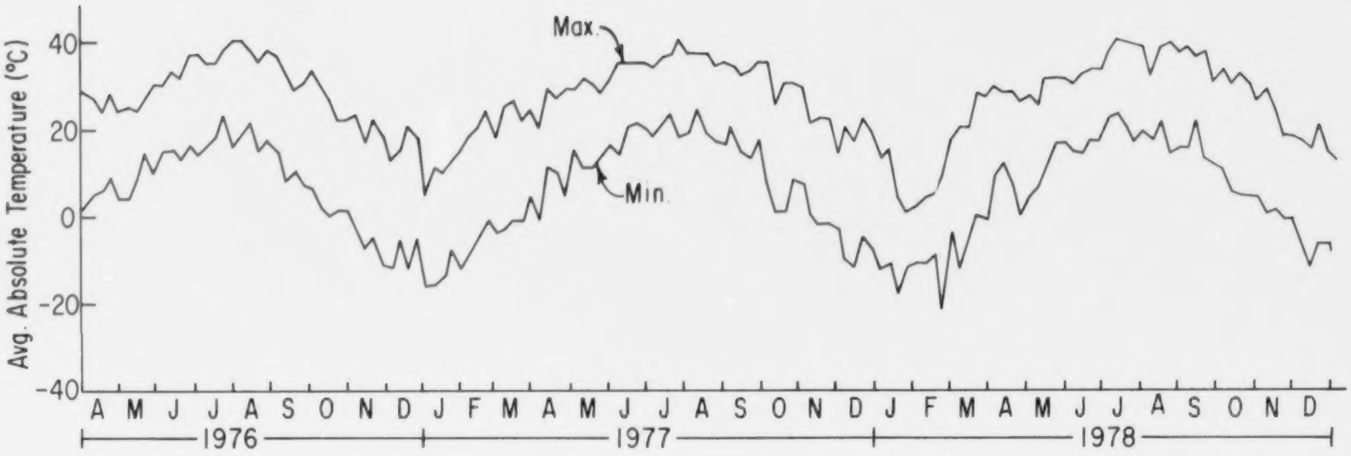

Figure 31. Weekly absolute maximum and minimum temperatures (C) during study period.

In general the maximum temperatures were not as high and the minimum temperatures were not as low as the long-term average. The absolute maximum temperature did not exceed 40 C in July, August and September and the absolute minimum temperature did not fall below -20 C in January as it usually does. The range between long-term average, absolute maximum and absolute minimum temperatures is about 50 C in January and 35 C in July. During the study period the range in these temperatures was only about 20 C in January and July.

WATER

Precipitation and Runoff

In an attempt to graphically show the relationship between seasonal precipitation and runoff during the study period, precipitation and runoff data per 10-day period are shown in Figure 32. Periods of 10 days were chosen as a compromise between maximizing the number of individual periods shown and trying to graphically isolate the effects of individual weather fronts passing through the area.

The limited number of runoff events is readily apparent. None occurred during the first 13 months of the study. The first runoff event produced the greatest amount of runoff. In that 10-day period about 25% of the 160+ mm precipitation moved off the watershed. All other 10-day periods had less than 60 mm of precipitation. The five 10-day periods with runoff after May, 1977 each received between about 45 and 60 mm of precipitation. Two of the seven 10-day periods receiving more than 45 mm of precipitation did not produce runoff. Although runoff events were infrequent, runoff occurred at least once during spring (April - May), summer (June - August), fall (September - November) and winter (December - March) seasons.

Precipitation per 7-day period was also computed. The precipitation class distribution, in 10-mm increments, is shown in Figure 33. There were 167 weeks during the study period. No precipitation fell in 48 weeks and less than 10 mm fell in 109 weeks or 65% of the total weeks of study period. Generally any rain of less than 10 mm is absorbed by dead or by live and dead tallgrass prairie standing vegetation and ground litter. This water is usually rapidly evaporated and does not affect plant growth or soil water recharge. When aboveground plant biomass is excessive (8,000 - 10,000 kg/ha), even rains of more than 10 or 15 mm will be ineffectual.

In this study the average aboveground plant biomass on the watershed at one time varied from 2500 to 6000 kg/ha depending on the season. The lowest amount usually occurred in very late winter after a long period of litter decomposition and before biomass replacement by new growth.

Monthly Summary of Rainfall and Runoff

Table 2 presents monthly summaries of rainfall and runoff at the environmental and the hydrology research watersheds from April 1976 through December 1979. It is clear that rainfall was uniformly distributed over the environmental watershed. The rainfall amounts recorded by gages RE-1 and RE-2 were

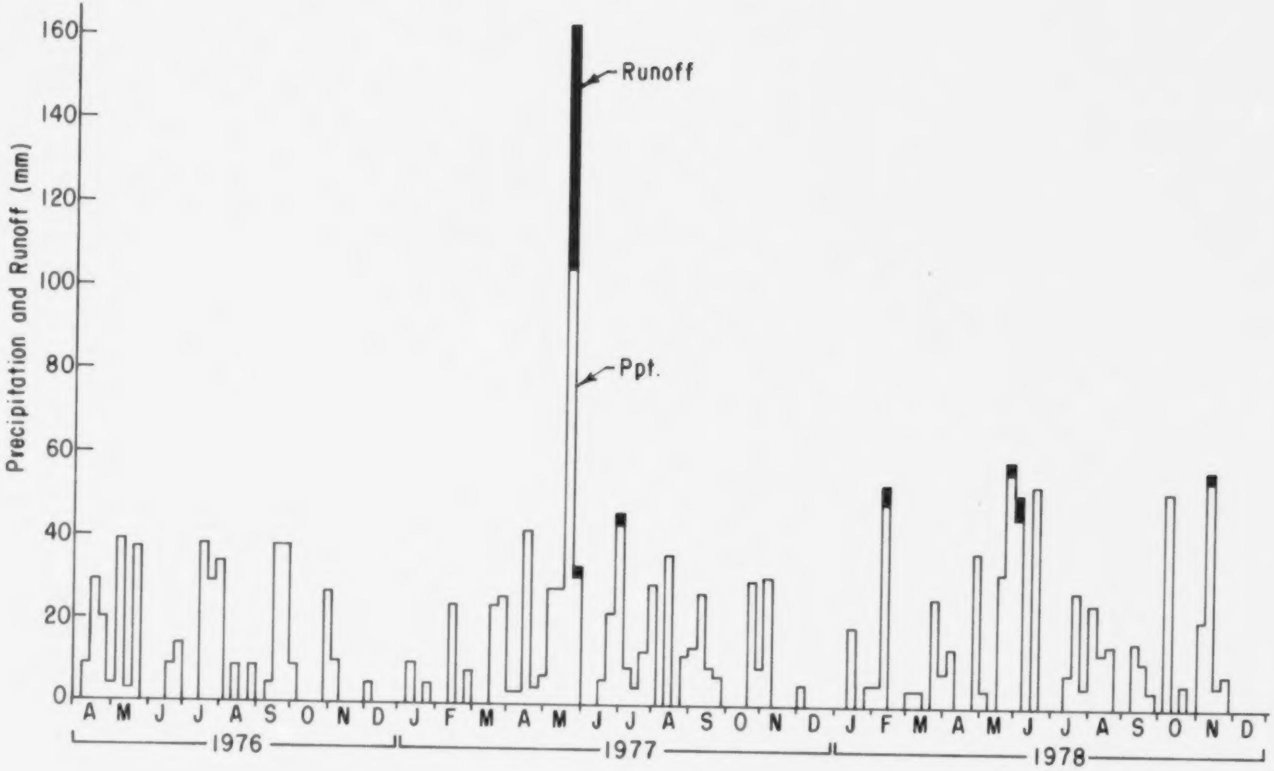

Figure 32. Precipitation and runoff for 10-day periods during study period.

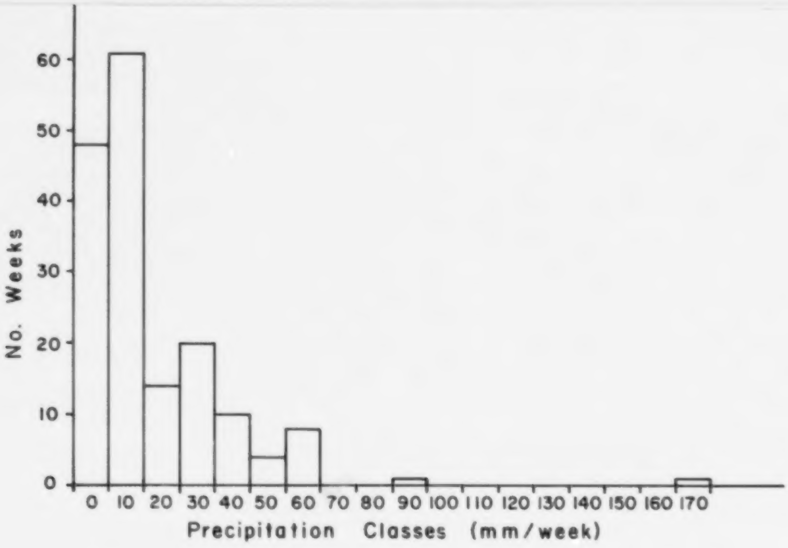

Figure 33. Number of weeks per precipitation class during study period.

not significantly different, although there was a very slight tendency for a greater amount to be recorded by RE-2 on the west, or upper end of the watershed.

Rainfall was below normal during the study period. The long-term average rainfall for Stillwater for the period 1893 - 1975 is listed in the first column of Table 2. The table shows that 30 months of the 44-month study period had rainfall amounts less than the long-term Stillwater average. By years, rainfall was 41% less than normal in 1976; 13% less in 1977; and 18% less in 1978. Only 1979 had rainfall greater than normal, with 7% greater. For the 44-month period the total rainfall was 16% less than normal.

Rainfall at the environmental watershed was slightly greater than at the two grassland hydrology research watersheds located 24 km away in a northeasterly direction (also 24 km north of Stillwater). There was considerable variation from year to year, but for the entire period the environmental watershed received 8% more rainfall than the hydrology research watersheds.

Runoff from the environmental watershed was less than from either of the hydrology research watersheds. For the entire period runoff was 9% less than from watershed WH-3 (37 ha) and 33% less than from watershed WH-1 (6.8 ha). The comparison between the environmental watershed and watershed WH-3 is important because WH-3 is comparable to the environmental watershed in size, vegetation cover, and grazing management. Thus it should be noted that runoff production from the environmental watershed was lower than from watershed WH-3, despite the fact that rainfall was 8% greater. The comparison with watershed WH-1 is less valid because that watershed is much smaller. More importantly, it is seriously overgrazed and has compacted soils due to overstocking, resulting in consistently larger runoff amounts.

TABLE 2. MONTHLY RAINFALL AND RUNOFF AMOUNTS, ENVIRONMENTAL AND HYDROLOGY RESEARCH WATERSHEDS, OKLAHOMA STATE UNIVERSITY

Month	Rainfall (mm)					Runoff (mm)		
	Stillwater Average	RE-1	RE-2	RH-1	RH-3	WE-1	WH-1	WH-3
Year: 1976								
April	85.1	62.0	61.8	96.3	86.4	0.00	6.76	4.34
May	120.4	79.9	77.4	53.8	50.6	1.96	0.23	0.00
June	92.0	24.1	21.6	15.2	17.3	0.00	0.00	0.00
July	70.6	63.8	68.1	32.5	33.5	0.00	0.00	0.00
August	67.8	50.6	53.4	42.9	39.6	0.00	0.00	0.00
September	96.3	78.2	89.6	106.9	99.8	0.00	0.00	0.00
October	96.3	39.9	39.8	46.0	45.0	0.00	0.61	0.00
November	51.8	10.2	10.2	5.3	7.6	0.00	0.79	0.00
December	34.0	4.5	5.6	2.3	2.3	0.00	0.00	0.00
TOTALS	714.3	413.2	427.5	401.2	382.1	1.96	8.39	4.34
Year: 1977								
January	28.4	15.3	15.3	15.2	15.2	0.00	0.00	0.00
February	31.8	30.3	29.0	39.4	39.4	0.00	0.66	0.18
March	54.1	51.9	52.8	38.6	39.4	0.00	1.45	0.41
April	85.1	52.3	52.2	74.9	71.9	0.00	5.72	1.78
May	120.4	251.2	259.6	224.5	211.8	59.43	103.43	69.85
June	92.0	29.8	27.9	81.0	81.3	0.00	1.37	0.25
July	70.6	100.5	96.2	33.3	31.8	2.75	0.58	0.13
August	67.8	54.2	52.8	88.1	89.2	0.00	0.00	0.00
September	96.3	57.6	56.5	92.2	84.1	0.00	72.21	0.10
October	96.3	36.2	38.4	21.6	20.6	0.00	0.00	0.00
November	51.8	34.1	34.1	51.3	50.0	0.00	3.23	0.56
December	34.0	6.8	7.3	7.4	7.4	0.00	0.00	0.00
TOTALS	828.6	720.2	722.1	767.5	742.1	62.18	118.65	73.26
Year: 1978								
January	28.4	26.1	23.1	17.3	19.1	0.00	0.20	0.00
February	31.8	64.8	61.9	60.5	57.9	3.40	46.00	7.06
March	54.1	35.7	37.9	36.3	35.8	0.18	1.32	4.17
April	85.1	36.7	37.9	44.2	44.7	0.00	1.32	4.78
May	120.4	121.7	117.2	129.8	122.9	2.48	6.27	21.31
June	92.0	103.0	107.7	56.9	66.3	6.23	0.00	0.00
July	70.6	36.5	37.9	52.8	49.0	0.00	0.00	0.00
August	67.8	58.7	57.7	60.7	60.5	0.00	0.00	0.00
September	96.3	31.8	32.8	16.3	24.4	0.00	0.00	0.00
October	96.3	57.9	59.2	26.9	27.7	0.00	0.00	0.00
November	51.8	90.0	94.7	92.5	91.9	1.52	0.00	0.00
December	34.0	11.4	10.9	11.9	15.2	0.00	0.00	0.00
TOTALS	828.6	674.3	678.9	606.1	615.4	13.81	55.11	37.32

(Continued)

TABLE 2. (Continued)

Month	Rainfall (mm)					Runoff (mm)		
	Stillwater Average	RE-1	RE-2	RH-1	RH-3	WE-1	WH-1	WH-3
Year: 1979								
January	28.4	39.5	35.0	33.8	34.5	8.35	1.57	7.49
February	31.8	8.1	9.2	8.6	10.7	0.00	0.00	0.00
March	54.1	94.0	94.6	102.1	98.0	19.18	32.08	41.00
April	85.1	53.5	49.6	59.9	57.7	2.18	8.48	9.22
May	120.4	124.1	123.5	87.4	81.3	33.28	28.52	12.67
June	92.0	130.0	131.8	120.9	120.7	10.36	16.21	11.13
July	70.6	141.7	153.7	52.8	50.3	27.00	0.00	0.00
August	67.8	69.8	76.7	72.9	72.6	0.00	0.00	0.00
September	96.3	56.4	60.2	37.1	34.3	0.00	0.00	0.00
October	96.3	37.6	34.8	38.4	36.6	0.00	0.00	0.00
November	51.8	77.2	78.7	81.8	77.0	0.84	0.00	0.00
December	34.0	47.0	45.2	45.2	41.4	0.54	0.00	0.00
TOTALS	828.6	878.9	893.0	740.9	715.1	101.73	86.86	81.51

Raingage and Watershed Code:

RE-1	Raingage No. 1, Environmental Research Watershed
RE-2	Raingage No. 2, Environmental Research Watershed
RH-1	Raingage No. 1, Hydrology Research Watershed W-1
RH-3	Raingage No. 3, Hydrology Research Watershed W-3
WE-1	Runoff Recorder, Main Weir, Environmental Research Watershed
WH-1	Runoff Recorder, Culvert Weir, Hydrology Research Watershed W-1
WH-3	Runoff Recorder, Culvert Weir, Hydrology Research Watershed W-3

Note:

1. Environmental Research Watershed is located 14 km northwest of Stillwater.
2. Hydrology Research Watersheds are located 24 km north of Stillwater.
3. Stillwater average rainfall is for the period 1893 - 1975.
4. Environmental Research Watershed was activated April 1, 1976.

Table 3 is a summary of the number and magnitude of rainfall events and related runoff events for each calender year of the study. There were a total of 274 rainfall events, of which 42 resulted in runoff. The ratio of runoff events to rainfall events is of particular interest. In 1976 only one of 20 rainfall events resulted in runoff. At that, the runoff was almost insignificant. In 1977 and 1978 there was an average of one runoff event for every nine rainfall events. The total observed runoff was five times greater in 1977 than in 1978, however. During 1979, when rainfall was higher than normal there was a runoff event for each 3.3 rainfall events. These data rather dramatically point up the vagaries of precipitation occurrence in the Great Plains region, and emphasize the importance of a hydrologic data base having a sufficiently long duration to eliminate erroneous conclusions due to variations in the precipitation cycle.

TABLE 3. SUMMARY OF RAINFALL AND RUNOFF EVENTS (APRIL 1976 - DECEMBER 1979), ENVIRONMENTAL RESEARCH WATERSHED, OKLAHOMA STATE UNIVERSITY

	Rainfall				Runoff		
Year	No of Events	Largest Event mm	Observed Total mm	Percent of Long-Term Average	No of Events	Largest Event mm	Observed Total mm
1976[1/]	40	39.5	420.4	59	2	0.97	1.96
1977	77	101.6	722.2	87	9	44.27	62.18
1978	84	51.3	676.6	82	9	5.82	12.44
1979	73	75.0	886.0	107	22	23.60	101.73

[1/] Period includes April - December only

Annual Maximum Rainfall Events

In hydrology the largest event of the year is referred to as the annual maximum. This event is of interest because the maximum value of either rainfall or runoff is used to develop an annual series by which the frequency of occurrence, or return period, of events of specified magnitude can be estimated.

The outstanding annual events observed in this study occurred on May 20, 1977; June 5, 1978; and July 17, 1979. Tables 4, 5, and 6 present a detailed analysis of the rainfall and runoff from each of those events, including antecedent rainfall, intensity of rainfall and accumulated amounts, and the rate and amount of runoff for various times throughout the rainfall and runoff period.

TABLE 4. ANNUAL MAXIMUM RUNOFF EVENT FOR 1977, ENVIRONMENTAL RESEARCH WATERSHED, OKLAHOMA STATE UNIVERSITY

EVENT OF MAY 20-21, 1977

Antecedent Conditions			Rainfall				Runoff			
Date Mo-Day	Rainfall (mm)	Runoff (mm)	Date Mo-Day	Time of Day	Intensity (mm/h)	Accum. (mm)	Date Mo-Day	Time of Day	Rate (mm/h)	Accum. (mm)
Rain Gage RE-1										
5-4	2.79	0.0	5-20	1845	0.00	0.00	5-20	2120	0.00	0.00
5-5	26.67	0.0		2010	1.27	0.51		2122	3.17	0.10
5-15	1.78	0.0		2025	6.10	2.03		2126	6.37	0.38
5-16	19.30	0.0		2035	1.52	2.28		2130	8.05	0.89
5-17	7.62	0.0		2055	12.95	6.60		2134	8.79	1.47
5-19	21.59	0.0		2105	56.39	16.00		2138	8.13	2.03
				2115	30.48	21.08		2145	9.70	3.05
				2125	9.14	22.60		2150	14.93	4.04
				2137	25.40	27.68		2154	28.37	5.43
				2150	121.92	54.10		2158	34.42	7.54
				2158	19.05	56.64		2202	40.21	10.06
				2208	11.17	58.67		2204	41.60	11.43
				2215	19.56	60.96		2208	38.17	14.09
				2240	18.79	68.83		2212	31.93	16.41
				2247	8.63	69.85		2216	25.55	18.34
				2255	28.70	73.66		2220	19.53	19.86
				2308	11.68	76.20		2224	14.27	20.95
				2315	21.84	78.74		2226	13.28	21.44
				2325	15.24	81.28		2230	10.92	22.22
				2400	0.51	81.53		2234	9.65	22.91
			5-21	0037	0.76	82.04		2238	8.84	23.52
				0047	0.00	82.04		2245	8.23	24.53
				0057	32.00	87.37		2256	7.69	25.98
				0115	24.64	94.74		2301	7.69	26.62
				0210	3.81	98.30		2312	8.10	28.09
				0230	0.76	98.55		2322	8.25	29.44
								2332	7.97	30.81
								2343	6.98	32.18
								2400	4.37	33.80
							5-21	0010	3.40	34.47
								0021	2.41	35.00
								0034	1.80	35.43
								0050	1.32	35.84
								0106	1.22	36.17
								0118	1.70	36.45
								0125	2.77	36.70
								0129	3.66	36.96
								0133	5.15	37.29
								0138	6.15	37.77
								0156	4.85	39.47
								0210	3.55	40.44
								0226	2.59	41.25
								0246	1.80	41.98
								0304	1.29	42.47
								0323	0.94	42.82
								0343	0.66	43.08
								0405	0.48	43.28
								0427	0.35	43.43
								0500	0.25	43.61
								0544	0.18	43.76
								0642	0.13	43.91
								1010	0.02	44.14
								1146	0.02	44.22
								1532	0.00	44.27

Total Watershed Area: 57.7 ha

Watershed Conditions: 94% native grass range, and 6% wheat. Native grass was in good condition with average composition of: 13% tallgrass; 16% midgrass; 5% shortgrass; 31% other grass; 31% forbs; 4% shrubs.

Note: Watershed has one 0.18 ha pond with 6.87 ha drainage area. Accumulated runoff in last column is discharge from main outlet weir only and does not include runoff water retained by the pond. Total watershed yield, corrected for pond effect was 47.02 mm.

To convert runoff in mm/h to m^3/s, multiply by 0.1597.

TABLE 5. ANNUAL MAXIMUM RUNOFF EVENT FOR 1978, ENVIRONMENTAL RESEARCH WATERSHED, OKLAHOMA STATE UNIVERSITY

Antecedent Conditions			Rainfall				Runoff			
Date Mo-Day	Rainfall (mm)	Runoff (mm)	Date Mo-Day	Time of Day	Intensity (mm/h)	Accum. (mm)	Date Mo-Day	Time of Day	Rate (mm/h)	Accum. (mm)
				EVENT OF JUNE 5, 1978						
	Rain Gage RE-1									
5-21	11.7	0.00	6-5	0345	0.00	0.00	6-5	0550	0.00	0.00
5-26	4.8	0.00		0400	6.10	1.52		0551	0.94	0.01
5-27	49.3	0.91		0442	1.45	2.54		0552	3.80	0.05
5-28	4.6	1.57		0458	0.95	2.79		0553	4.54	0.12
6-4	0.5	0.00		0505	97.97	13.22		0554	5.04	0.20
				0515	6.10	15.24		0555	4.87	0.28
				0520	118.87	25.15		0600	4.76	0.68
				0530	10.67	26.92		0602	4.33	0.83
				0540	1.52	27.17		0604	4.19	0.97
				0558	33.02	37.08		0612	4.67	1.56
				0638	2.67	38.86		0615	4.41	1.79
				0705	4.52	40.89		0618	4.02	2.00
				0730	0.00	40.89		0622	3.61	2.25
				0908	1.24	42.67		0631	2.65	2.73
								0640	1.92	3.07
								0648	1.39	3.29
								0657	1.13	3.48
								0702	0.97	3.56
								0706	0.86	3.63
								0714	0.75	3.73
								0718	0.64	3.78
								0722	0.62	3.82
								0731	0.53	3,91
								0740	0.42	3.98
								0749	0.35	4.04
								0758	0.30	4.09
								0806	0.24	4.12
								0815	0.21	4.16
								0824	0.19	4.19
								0832	0.16	4.21
								0841	0.14	4.24
								0850	0.13	4.25
								0859	0.12	4.27
								0904	0.11	4.28
								0908	0.10	4.29
								0917	0.09	4.30
								1000	0.07	4.35
								1100	0.03	4.39
								1200	0.02	4.42
								1300	0.00	4.43

Total Watershed Area: 57.7 ha

Watershed Conditions: 94% native grass range, and 6% wheat. Native grass was in good condition with average composition of: 13% tallgrass; 16% midgrass; 5% shortgrass; 31% other grass; 31% forbs; 4% shrubs.

Note: Watershed has one 0.18 ha pond with 6.87 ha drainage area. Accumulated runoff in last column is discharge from main outlet weir only and does not include runoff water retained by the pond. Total watershed yield, corrected for pond effect was 5.82 mm.

To convert runoff in mm/h to m^3/s, multiply by 0.1597.

TABLE 6. ANNUAL MAXIMUM RUNOFF EVENT FOR 1979, ENVIRONMENTAL RESEARCH WATERSHED, OKLAHOMA STATE UNIVERSITY

Antecedent Conditions			Rainfall				Runoff			
Date Mo-Day	Rainfall (mm)	Runoff (mm)	Date Mo-Day	Time of Day	Intensity (mm/h)	Accum. (mm)	Date Mo-Day	Time of Day	Rate (mm/h)	Accum. (mm)
				EVENT OF JULY 17, 1979						
Rain Gage RE-1										
7-05	42.9	1.24	7-17	0255	0.0	0.00	7-17	0317	0.00	0.00
7-06	8.9	2.03		0300	79.2	6.60		0318	0.88	0.00
7-07		0.03		0305	109.7	15.75		0319	3.78	0.05
				0315	94.5	31.50		0320	5.14	0.12
				0325	79.2	44.70		0322	7.76	0.32
				0330	79.2	51.31				
				0340	59.4	61.21		0324	13.47	0.53
				0350	33.5	66.80		0326	19.38	1.30
				0400	6.1	67.82		0331	21.10	3.04
				0410	7.6	69.09		0332	25.11	3.40
				0453	7.0	70.61		0334	30.18	4.37
				0515	6.9	73.15				
				0545	3.6	74.93		0338	31.15	6.41
				0700	1.0	76.20		0340	31.11	7.38
Rain Gage RE-2								0342	29.67	8.45
								0346	27.40	10.35
7-05	44.2	1.24	7-17	0255	0.0	0.00		0356	18.78	14.13
7-06	8.4	2.03		0300	143.3	11.94				
7-07		0.03		0305	143.3	23.88		0403	12.74	15.98
				0315	134.1	46.23		0411	8.01	17.36
				0325	102.1	63.25		0418	5.62	18.16
				0330	64.0	68.58		0424	4.64	18.68
				0340	53.3	77.47		0433	3.60	19.29
				0400	5.3	79.25				
				0410	15.2	81.53		0441	2.86	19.72
				0440	1.5	82.30		0448	2.46	20.03
				0515	8.5	85.85		0456	2.02	20.33
				0700	2.3	87.63		0503	1.91	20.56
								0512	1.74	20.84
								0520	1.54	21.06
								0527	1.46	21.23
								0534	1.32	21.39
								0541	1.21	21.54
								0549	1.10	21.70
								0556	0.99	21.82
								0602	0.94	21.92
								0611	0.84	22.05
								0619	0.75	22.16
								0626	0.66	22.24
								0634	0.62	22.32
								0659	0.44	22.54
								0730	0.31	22.74
								0800	0.25	22.88
								0920	0.13	23.13
								1105	0.07	23.30
								1236	0.04	23.38
								1415	0.03	23.45
								1700	0.02	23.52
								1830	0.01	23.54
								2000	0.01	23.56
								2400	0.00	23.60

Total Watershed Area: 57.7 ha

Watershed Conditions: 94% native grass range, and 6% wheat. Native grass was in good condition with average composition of: 13% tallgrass; 16% midgrass; 5% shortgrass; 31% other grass; 31% forbs; 4% shrubs.

Note: Watershed has one 0.18 ha pond with 6.87 ha drainage area. Accumulated runoff in last column is discharge from main outlet weir only and does not include runoff water retained by the pond. Total watershed yield, corrected for pond effect was 24.18 mm.

To convert runoff in mm/h to m^3/s, multiply by 0.1597.

The annual events can be put into better perspective if they are compared to historical values available in the hydrology literature. Table 7 lists rainfall intensity frequencies for rainfall durations of 5 minutes to 2 hours for return periods of 2 to 100 years. These data were compiled for the Stillwater, Oklahoma vicinity from National Weather Service publications by Frederick, Myers, and Auciello (1977) and Hershfield (1961). Table 7 was used as the basis for determining the return periods of rainfall intensities at the environmental watershed.

Table 8 shows the observed rainfall intensities and the estimated return periods for the annual maximum events. One of the events, June 5, 1978, had only moderate rainfall intensities, with no return periods greater than one to two years. The May 20, 1977 event had higher intensities throughout with a return period of 5 years for a 2-hour duration. The return periods for the entire storm ranged between 2 and 5 years. The most intense storm of the entire study was the July 17, 1979 event, which had very high intensities throughout its life. The return period was 25 to 50 years for a 30-minute duration and 25 years for a 60-minute duration. Even the intensity for the 2-hour duration had a return period of 10 years. Storms of this duration and intensity usually cause a considerable amount of erosion. The sediment load carried by runoff from this storm is discussed elsewhere in this report.

Annual Maximum Runoff Events

The results of a flow duration analysis for each of the annual maximum events (Table 9) show the maximum discharge rate and the runoff distribution for various times from 1 hour to 8 days. In general, about half of the runoff from the environmental watershed occurred in the first two hours. Runoff was essentially completed after six hours, illustrating the ephemeral nature of the watershed.

For purposes of comparison, Table 9 also contains similar flow duration analyses for hydrology research watersheds WH-1 and WH-3. As noted previously there is a great deal of similarity in cover and management between hydrology watershed WH-3 and the environmental watershed WE-1. However, direct comparison is difficult because of differences in rainfall due to geographic separation of the watersheds. The May 20, 1977 event is the only one common to all three watersheds. It may be noted though that all three watersheds had approximately half of the runoff in the first two hours and that runoff was completed in the first six hours.

Comparing watersheds WE-1 and WH-3, it may be noted that the maximum discharge rate for the environmental watershed was more than twice as large as the hydrology watershed, while the total amount of runoff was considerably less. After 1 day the runoff from WE-1 was 44.28 mm compared with 55.39 mm from WH-3. This may possibly be explained by the topography of the two watersheds. The environmental watershed had a much shorter time of concentration because its main drainageway has two principal branches. The hydrology watershed has a single main waterway and therefore has a longer time of concentration, resulting in a lower peak discharge rate than the environmental watershed.

TABLE 7. NWS PRECIPITATION[1] INTENSITY FREQUENCY TABLE FOR STILLWATER, OKLAHOMA

Return Period yr.	Precipitation Intensity For Duration of 5 min.	10 min.	15 min.	30 min.	60 min.	2 hr.
	mm/hr					
2	128	196	90	64	41	26
5	168	137	117	84	56	35
10	189	157	134	98	66	41
25	222	183	155	116	78	48
50	244	203	172	130	87	54
100	267	221	188	143	96	60

Reference: Frederick, R.H., V.A. Myers and E.P. Auciello. Five to 60-minute Precipitation Frequency for the Eastern and Central United States. NOAA Technical Memorandum NWS HYDRO-35, June, 1977.

[1] Precipitation values were converted to Annual Series by applying conversion factors listed in Table 1 of reference publication.

TABLE 8. PRECIPITATION INTENSITY AND RETURN PERIOD FOR ANNUAL MAXIMUM RUNOFF EVENTS, ENVIRONMENTAL RESEARCH WATERSHED, OKLAHOMA STATE UNIVERSITY

	Duration 5 min.	10 min.	15 min.	30 min.	60 min.	2 hr.
	20 May 1977 Event					
Intensity (mm/hr)	152	137	110	65	49	34
Return Period (yrs)	2 5	5	2 5	2	2 5	5
	5 June 1978 Event					
Intensity (mm/hr)	118	75	53	53	37	21
Return Period (yrs)	1 2	1	1	1 2	1 2	1 2
	17 July 1979 Event					
Intensity (mm/hr)	143	149	140	126	79	42
Return Period	2 5	5 10	10 25	25 50	25	10

TABLE 9. ANNUAL MAXIMUM DISCHARGES AND ANNUAL MAXIMUM VOLUMES OF RUNOFF FOR SELECTED TIME INTERVALS, ENVIRONMENTAL AND HYDROLOGY RESEARCH WATERSHEDS, OKLAHOMA STATE UNIVERSITY

Year	Maximum Discharge		Maximum for Selected Time													
			1 Hour		2 Hours		6 Hours		12 Hours		1 Day		2 Days		8 Days	
	Date	Rate m³/s	Date	Vol. mm	Date	Vol. mm	Date	Vol. mm	Date	Vol. mm	Date	Vol. mm	Date	Vol. mm	Date	Vol. mm
ENVIRONMENTAL RESEARCH WATERSHED WE-1																
1976	5-12	0.07	5-12	0.36	5-12	0.55	5-12	0.92	5-12	1.02	5-12	1.02	5-12	1.02	5-12	1.02
1977	5-20	6.63	5-20	21.52	5-20	29.64	5-21	42.76	5-21	44.10	5-21	44.28	5-22	44.28	5-28	59.69
1978	6-5	0.80	6-5	3.34	6-5	4.04	6-5	4.42	6-5	4.43	6-5	4.43	6-6	4.50	6-6	4.50
1979	7-17	4.96	7-17	18.21	7-7	20.99	7-17	23.11	7-17	23.47	7-18	23.61	5-4	28.36	6-9	32.02
HYDROLOGY RESEARCH WATERSHED WH-1																
1976	4-20	0.03	4-20	1.25	4-20	2.17	4-20	3.21	4-20	3.73	4-20	4.45	4-20	4.45	4-20	5.96
1977	5-21	1.66	5-21	25.71	5-21	33.54	5-21	71.67	5-21	73.11	5-21	73.45	5-21	75.66	5-27	88.29
1978	2-12	0.15	2-12	7.10	2-12	13.02	2-12	26.52	2-12	30.60	2-13	33.24	2-13	33.58	2-13	33.58
1979	6-9	0.29	6-9	9.83	6-9	13.24	6-9	14.79	5-3	16.54	5-4	25.40	5-4	28.51	6-9	28.51
HYDROLOGY RESEARCH WATERSHED WH-3																
1976	4-20	0.12	4-20	1.04	4-20	1.78	4-20	2.94	4-20	3.35	4-20	3.76	4-20	3.76	4-28	4.12
1977	5-21	3.06	5-21	19.35	5-21	26.13	5-21	52.19	5-21	54.96	5-21	55.39	5-21	55.71	5-30	67.89
1978	5-28	0.37	5-28	3.15	5-28	5.80	5-28	12.24	5-28	15.38	5-28	18.08	5-28	18.08	5-28	18.08
1979	3-22	0.97	3-22	7.36	3-22	13.43	3-22	23.89	3-22	25.81	3-23	27.78	3-23	28.37	4-10	40.99

Sediment and Nutrient Sampling and Analyses

Table 10 contains a list of the sediment and nutrient constituents that were analyzed from samples collected from the runoff discharge. Also listed are the number of runoff events for which each constituent was sampled during the years 1977 - 1979. In general, except for sediment, each of the nutrients was sampled two to four times during each year, with the median number of events being three. We believe this number is sufficient to indicate the degree of nonpoint source pollution by runoff from the environmental watershed. Sediment was collected only once in 1978 but in 1979, sediment samples were collected during seven runoff events, including the outstanding hydrologic event of July 17, 1979. BOD was sampled only in 1977. Due to the difficulty and cost of having these samples analyzed for BOD, this test was discontinued after 1977.

TABLE 10. SAMPLING FREQUENCY FOR SEDIMENTS AND NUTRIENTS

Nutrient Sampled	No. of Runoff Events Sampled in Year		
	1977	1978	1979
Sediment	4	1	7
N in Sediment	4	2	3
NH_4 - N	4	2	3
NO_3 - N	4	2	3
NO_2 - N	0	1	3
Dissolved P	4	3	3
Total P	3	3	3
Dissolved K	3	1	3
Total K	0	3	3
COD	3	3	3
TOC	4	3	3
BOD	3	0	0

Detailed sediment and nutrient analysis data for each event sampled are listed in Appendix E. These basic data are point values of the sediment and nutrient content of each sample, together with the runoff rate and the accumulated runoff at the time each sample was obtained. The total sediment loss or nutrient loss was calculated for each event by an integration procedure which involved multiplying the average nutrient concentration during a time element by the amount of runoff that occurred during that time element.

The tables included in Appendix F illustrate the calculation procedure for determining the amount of sediment lost during each time interval of the event. The other nutrient losses were calculated by the same procedure, but the detailed calculations are not included with this report.

Summary of Sediment Loss by Runoff

Table 11 shows sediment loss rates for the 12 runoff events in terms of watershed area and also in terms of the amount of runoff. As expected the larger runoff events produced the greatest sediment losses per hectare. However, when expressed in terms of kilograms per hectare per millimeter of runoff, the sediment loss rates were quite similar for most of the events. The weighted average sediment/runoff ratio was 17.38 kg/ha/mm.

TABLE 11. SUMMARY OF SEDIMENT LOSS BY RUNOFF, ENVIRONMENTAL RESEARCH WATERSHED, OKLAHOMA STATE UNIVERSITY

Runoff Date	Rainfall mm	Runoff mm	Sediment Loss kg/ha	Sed/Runoff Ratio kg/ha/mm
20 May 77	101.55	44.27	687.6	15.53
23 May 77	38.61	13.56	193.7	14.28
27 May 77	22.35	1.85	6.9	3.75
1 July 77	45.72	1.72	32.1	18.68
14 Nov. 78	47.75	0.94	6.8	7.30
18 March 79	20.32	0.56	11.8	21.21
22 March 79	55.37	16.43	411.3	25.03
10 April 79	26.92	1.85	34.7	18.70
2 May 79	99.31	32.03	294.7	10.55
9 June 79	75.95	8.76	126.0	14.39
5 July 79	52.07	2.36	25.9	10.98
17 July 79	82.55	23.47	737.6	31.43
TOTALS	668.47	147.80	2569.1	

Weighted Average Sediment/Runoff Ratio = 17.38 kg/ha/mm

Two events differed significantly from the weighted average. The May 27, 1977 ratio of 3.75 kg/ha/mm was extremely low, which could be attributed to the small amount and low intensity of the rainfall. The July 17, 1979 event had the highest loss ratio, 31.43 kg/ha/mm. As previously noted this storm had a very high intensity and was classified as having a return period of 25 to 50 years for a duration of 30 minutes. Undoubtedly the high sediment loss rate was associated with the high rainfall intensity.

While the loss rates from the May 20, 1977 and July 17, 1979 events may seem high, they are low when compared with sediment losses reported for several grazed, tallgrass prairie pastures near Chickasha, Oklahoma as reported by Olness et al. (1975). They observed that one event with 89 mm rainfall caused sediment losses of 4.6 metric tons/ha from one watershed and 11.4 mt/ha from another watershed. Both events were for durations of less than 24 hours. In contrast, the sediment production from the May 20 event on the environmental watershed was 0.69 mt/ha. The high intensity storm of July 17 caused a sediment loss of only 0.74 mt/ha. Both of these amounts were significantly less than reported at the Chickasha watersheds.

The source of sediment is an important consideration in nonpoint source pollution studies. Sediment in the streamflow may come from soil erosion on the watershed or it may come from erosion caused by cattle paths, or by overcutting at points where concentrated flow enters the small tributaries of the main stream, or by erosion of the banks of the main stream when flows reach sufficient depth and velocity to dislodge loosely held soil particles from steep banks.

Bare or poorly vegetated areas in the watershed may yield significant amounts of sediment during high intensity rainfall due to the impact of raindrops on unprotected soil. This type of erosion should be at a minimum on a well-managed rangeland because of an abundance of herbaceous plant cover. We believe very little of the sediment loss from the environmental watershed was caused by raindrop impact on bare areas. Frequent observations while walking over the watershed during rainfall showed that the water passing over and through the vegetation by overland flow was relatively free of sediment. The first sign of sediment in the runoff occurred at the overfall or head cut that existed where cattle trails entered the main stream. Another source of sediment was the field access road at the west side of the watershed.

Stream bank erosion is less subject to control by good range management practices. If the channel grade is not completely stabilized, or if the banks are steep, a considerable amount of sediment may be injected into the flow because of sloughing of the banks. Inspection of the watershed during rainfall leads us to the conclusion that bank erosion was largely responsible for the sediment load that was collected at the lower end of the watershed.

Nitrogen Losses by Runoff

Nitrogen losses were evaluated for nine runoff events. The results are summarized in Table 12. The nitrogen loss in the sediment accounted for practically all of the losses of N. Dissolved nitrogen losses in the forms of NH_4-N, NO_3-N, and NO_2-N were very low and could be considered insignificant. Considering the fact this watershed have never received an application of commercial fertilizer, this finding is not unexpected.

The results of two comparable studies, one in Oklahoma and one in west-central Minnesota, may be used for comparison with the total N loss observed on the environmental watershed. Olness et al. (1975) studied the influence of management practices on two tallgrass watersheds at Chickasha, Oklahoma, on losses of nitrogen and phosphorous in the runoff from July, 1972 to July 1973. Total N loss from a rotationally grazed pasture was 1.59 kg/ha. A continuously grazed pasture lost 7.87 kg/ha of N. Total nitrogen loss from the environmental watershed for 19/7, the only year for which complete data exists, amounted to 4.64 kg/ha which compares quite well with the Chickasha results.

TABLE 12. SUMMARY OF NITROGEN LOSS BY RUNOFF, ENVIRONMENTAL RESEARCH WATERSHED, OKLAHOMA STATE UNIVERSITY

Runoff	Sediment		Filtrate					
Date	TN-N[1/]		NH_4-N		NO_3-N		NO_2-N	
	Kg/ha	Kg/ha/mm	Kg/ha	Kg/ha/mm	Kg/ha	Kg/ha/mm	Kg/ha	Kg/ha/mm
20 May 77	3.229	0.0729	0.0359	0.0008	0.0834	0.0019	--[2/]	---
23 May 77	0.965	0.0712	0.0126	0.0009	0.0149	0.0011	--	---
27 May 77	0.083	0.0449	0.0046	0.0025	0.0055	0.0030	--	---
1 July 77	0.196	0.1140	0.0014	0.0008	0.0014	0.0008	--	---
5 June 78	---	---	0.0085	0.0019	0.0039	0.0008	--	---
21 June 78	---	---	0.0001	0.0011	0.0001	0.0012	*[3/]	*
18 March 79	0.013	0.0236	0.0037	0.0066	0.0010	0.0017	0.00005	0.00009
22 March 79	0.248	0.0151	0.0978	0.0060	0.0077	0.0005	0.00100	0.00006
2 May 79	0.689	0.0215	0.0393	0.0012	0.0042	0.0001	*	*

[1/] TN-N is total nitrogen.
[2/] Nutrient not evaluated during this event.
[3/] Nutrient not detected during this event.

In Minnesota, Timmons and Holt (1977) measured nitrogen losses in surface runoff from a tallgrass prairie during 1970 - 1974. The average annual total N loss for that 5-year period was 0.84 kg/ha. The lowest and highest observed annual losses were 0.11 and 1.71 kg/ha, respectively. Thus the loss observed at the environmental watershed was more than twice as large as the highest annual loss observed in Minnesota. However, the amount and character of the rainfall may have been a factor. Average annual rainfall in Minnesota during the study was 595 mm compared with 722 mm at Stillwater in 1977.

Phosphorus and Potassium Losses by Runoff

Table 13 is a summary of phosphorus (P) and potassium (K) losses by runoff. Dissolved P was measured for 10 events and total P was determined for nine events. The data are shown in units of kilograms per hectare of watershed area for comparison with other studies, and also in units of kilograms per hectare per millimeter of runoff for comparison of events with different amounts of runoff.

Total P losses from the environmental watershed were in the same order of magnitude as had been observed at the Minnesota watershed by Timmons and Holt (1977). Total P losses for 1977, 1978, and 1979 were 0.010, 0.006, and 0.228 kg/ha, respectively. The 5-year average in the Minnesota study was 0.11 kg/ha, with individual years ranging from 0.01 to 0.25 kg/ha per year. The total P losses at the environmental watershed were much less than reported by Olness et al. (1975) for the Chickasha, Oklahoma study. Losses there amounted to 1.27 kg/ha from the rotationally grazed pasture and 4.60 kg/ha from the continuously grazed pasture. None of the pastures had been fertilized with commercial fertilizer.

Potassium losses for the environmental watershed also compared favorably with the Minnesota watershed. Total potassium losses amounted to 1.06 kg/ha in 1978 and 5.28 kg/ha in 1979. In Minnesota the range was from 0.25 to 3.98 kg/ha, with an average value of 1.74 kg/ha. In terms of total K losses per millimeter of runoff from the environmental watershed, the losses for the six events in 1978 and 1979 ranged from 0.08 to 0.26 kg/ha/mm.

BOD, COD, and TOC in Runoff

Biological oxygen demand (BOD), chemical oxygen demand (COD) and total organic carbon (TOC) are commonly used indicators of water quality. The summary of the analyses for these parameters is presented in Table 14. BOD was evaluated for three events in 1977. COD was determined for three events in each year of 1977, 1978, and 1979. TOC was evaluated for four events in 1977 and three each in 1978 and 1979.

The total BOD load for 1977 was 1.40 kg/ha with a range of 0.021 to 0.065 kg/ha/mm of runoff. The highest COD load occurred in 1979 with a total of 34.87 kg/ha. The lowest COD was in 1978 with 4.63 kg/ha. There was a substantial increase in the COD load per millimeter of runoff over the years. For 1977 the COD loss ranged from 0.31 to 0.45 kg/ha/mm; in 1978 it ranged

TABLE 13. SUMMARY OF PHOSPHORUS AND POTASSIUM LOSS BY RUNOFF, ENVIRONMENTAL RESEARCH WATERSHED, OKLAHOMA STATE UNIVERSITY

Runoff Date	Dissolved P		Total P		Dissolved K		Total K	
	Kg/ha	Kg/ha/mm	Kg/ha	Kg/ha/mm	Kg/ha	Kg/ha/mm	Kg/ha	Kg/ha/mm
20 May 77	0.0064	0.0001	0.0064	0.0001	1.4569	0.0329	---[1]	---
23 May 77	0.0033	0.0002	0.0047	0.0004	0.5093	0.0376	---	---
27 May 77	0.0002	0.0001	0.0004	0.0002	0.0909	0.0492	---	---
1 July 77	0.0004	0.0002	(1)		0.0549	0.0320	---	---
5 June 78	0.0014	0.0003	0.0055	0.0012	---	---	0.9160	0.2072
21 June 78	0.0001	0.0007	0.0001	0.0004	---	---	0.0188	0.2089
14 Nov 78	0.0006	0.0007	0.0008	0.0009	0.0349	0.0371	0.1273	0.1354
18 March 79	0.0006	0.0011	0.0022	0.0039	0.0174	0.0311	0.1441	0.2573
22 March 79	0.0139	0.0008	0.0828	0.0050	0.4106	0.0250	2.4579	0.1496
2 May 79	0.0381	0.0012	0.143	0.0044	0.9644	0.0301	2.682	0.0838

[1] Analysis not conducted during this event.

TABLE 14. SUMMARY OF BOD, COD, AND TOC LOSS BY RUNOFF, ENVIRONMENTAL RESEARCH WATERSHED, OKLAHOMA STATE UNIVERSITY

Runoff Date	BOD		COD		TOC	
	Kg/ha	Kg/ha/mm	Kg/ha	Kg/ha/mm	Kg/ha	Kg/ha/mm
20 May 77	0.938	0.0212	13.532	0.306	4.515	0.102
23 May 77	0.345	0.0255	5.241	0.386	1.756	0.130
27 May 77	0.120	0.0649	0.832	0.450	0.362	0.196
1 July 77	---[1]	---	---	---	0.242	0.141
5 June 78	---	---	3.954	0.894	0.710	0.161
21 June 78	---	---	0.062	0.690	0.028	0.304
14 Nov 78	---	---	0.614	0.653	0.282	0.300
18 March 79	---	---	0.946	1.690	0.322	0.574
22 March 79	---	---	19.745	1.202	7.238	0.440
2 May 79	---	---	34.875	1.089	9.123	0.285

---

[1] Analysis not conducted during this event.

from 0.65 to 0.89 kg/ha/mm; and in 1979 it ranged from 1.20 to 1.69 kg/ha/mm. The TOC load also showed an increase over the three years in about the same proportion as the COD.

HYDROGRAPHS

Rainfall histograms and runoff hydrographs are shown in Figures 34 - 43 for the most significant hydrologic events in 1977 - 1979. These figures also show the time of collection and sediment load of each runoff sample and the accumulated amounts of sediment and runoff. As a general rule the sediment load was closely associated with the runoff rate. This relationship is illustrated quite clearly in Figures 34 and 43, which portray the rainfall, runoff and sediment relationships for the outstanding hydrologic events of May 20-21, 1977 and July 17, 1979.

Figures 44 and 45 show the variation of the BOD, COD, and TOC parameters with the runoff from the events of May 20, 1977 and June 5, 1978, respectively. The BOD decreased significantly during the runoff period for the May 20 event. This would indicate organic matter was transported from the watershed with the first flush of runoff. The COD parameter value also decreased sharply from its initial value of 40 mg/1, but stablilzed at an average value of 26 mg/1 approximately 30 minutes after the beginning of runoff. The TOC values followed the same pattern, decreasing from an initial value of 13.5 mg/1 to an average value of 9.4 mg/1 after 30 minutes.

The pattern for the June 5, 1978 event was somewhat different from the May 20, 1977 event because the runoff rate was much lower. The peak runoff rate for June 5 was 0.68 m^3/sec compared with 6.27m^3/ sec for May 20. In the June 5 event the COD value peaked when the runoff rate peaked, increasing from an initial value of 80 mg/1 to a maximum of 140 mg/1 and then stabilizing at an average of 50 - 55 mg/1 approximately one hour after the peak runoff rate. The initial value of the TOC parameter was the highest (20.4 mg/1). TOC decreased rapidly to 15.6 mg/1 reaching its lowest value (13.9 mg/1) about one hour after runoff began, and then increased to an average value of 17 mg/1. Examination of the basic data in Appendix E shows that TOC was a less sensitive parameter than the COD parameter for the runoff events observed at the environmental watershed.

SOILS

Soil Depth and Texture

Soil depth and horizon thickness and texture composition for each of the 29 sampling locations are shown in Figure 46. Detailed profile descriptions of the sampling locations are shown in Appendix G.

Soil depths ranged from 26 to 150 cm with an average of 75±35 cm. All soils included an A1 horizon and one or more B horizons. Thickness of the A horizon ranged from 10 to 45 cm with an average of 17±7 cm. Most of the soils had a loam A1 horizon texture. Other A1 horizon textures included silt loam and sandy loam. The average soil texture composition for A1 horizons were 47±11% sand, 30±8% silt, and 23±4% clay.

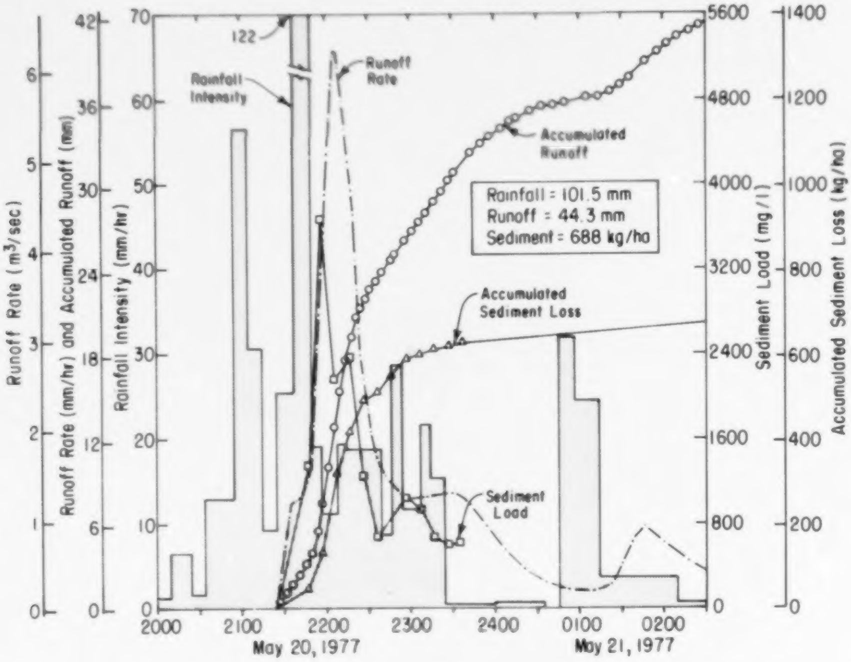

Figure 34. Hydrograph for event of May 20-21, 1977.

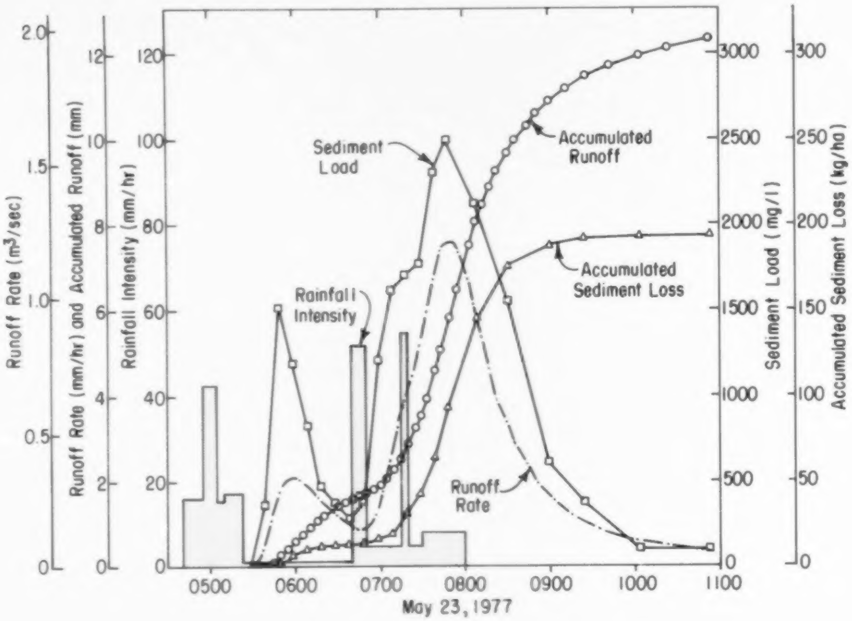

Figure 35. Hydrograph for event of May 23, 1977.

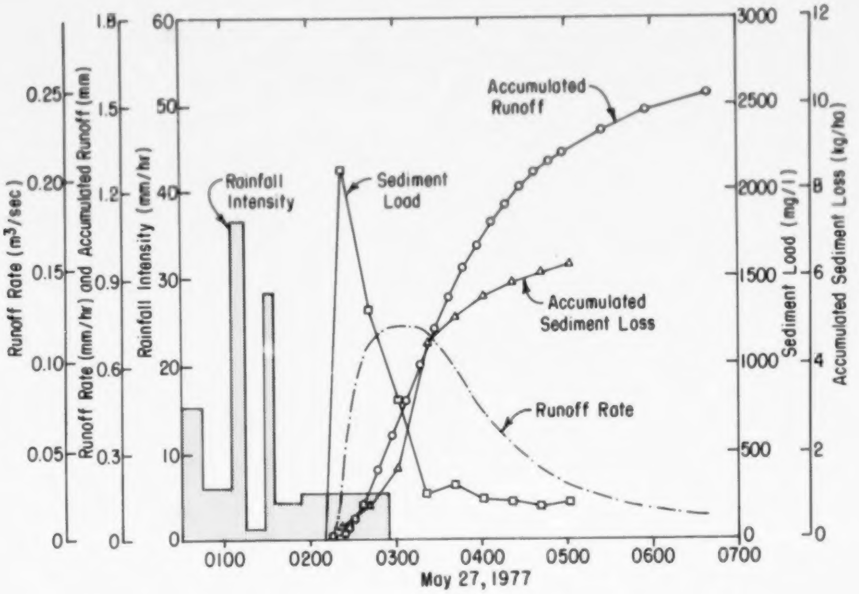

Figure 36. Hydrograph for event of May 27, 1977.

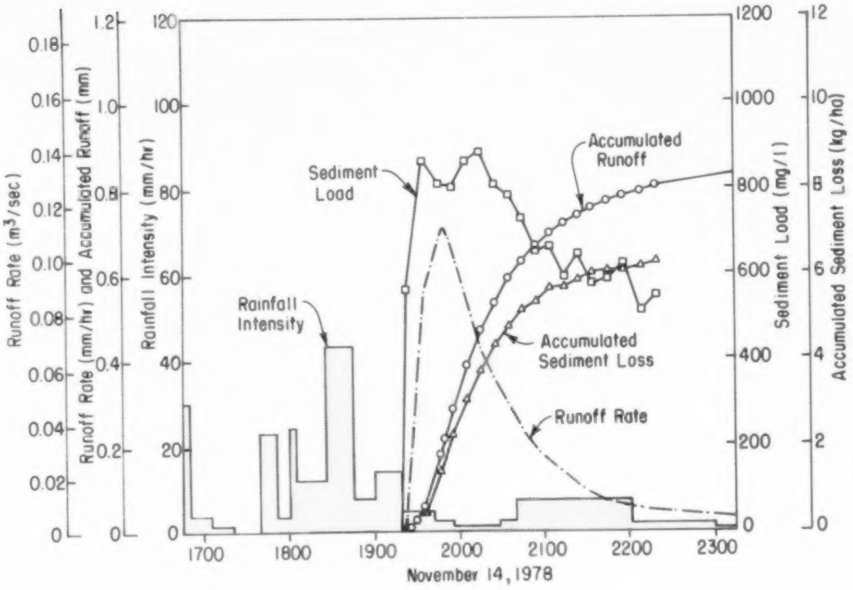

Figure 37. Hydrograph for event of November 14, 1978.

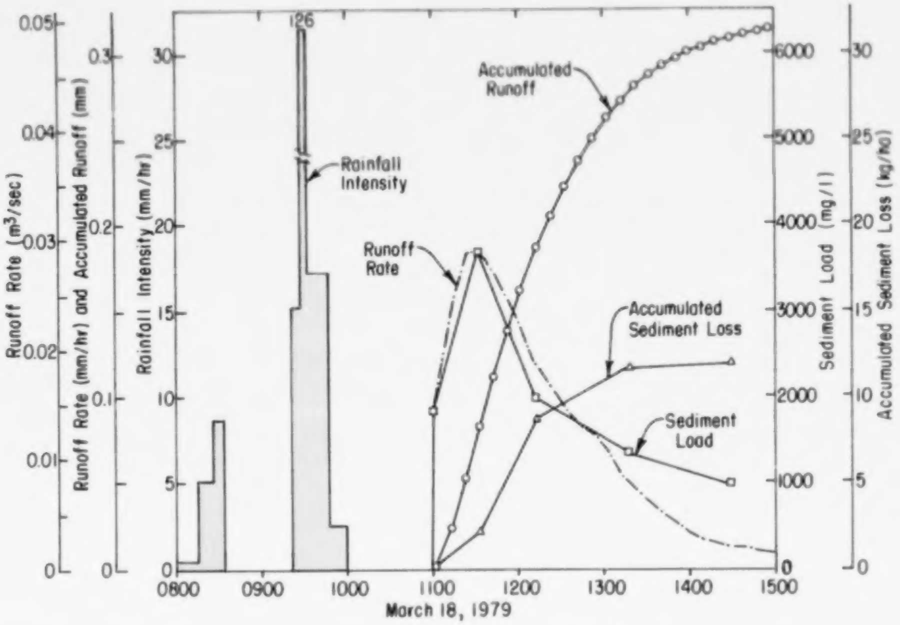

Figure 38. Hydrograph for event of March 18, 1979.

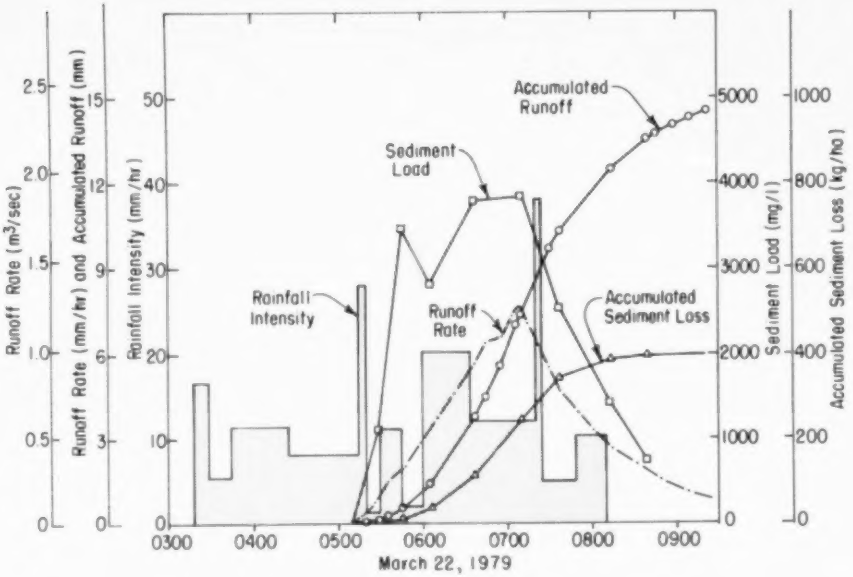

Figure 39. Hydrograph for event of March 22, 1979.

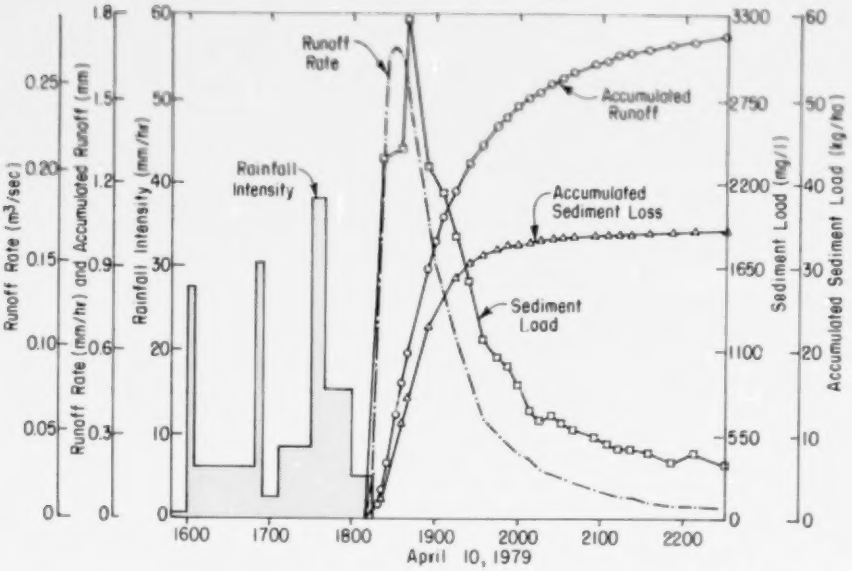

Figure 40. Hydrograph for event of April 10, 1979.

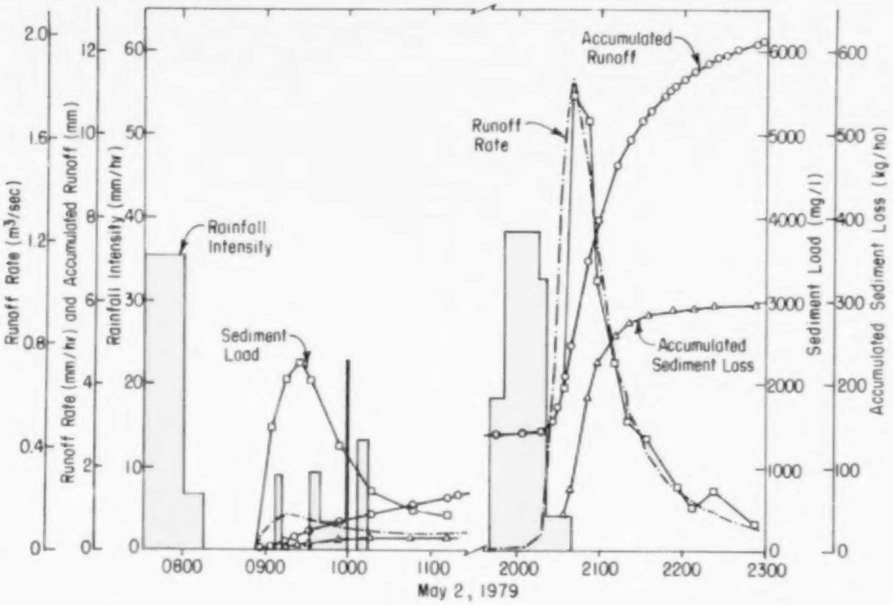

Figure 41. Hydrograph for event of May 2, 1979.

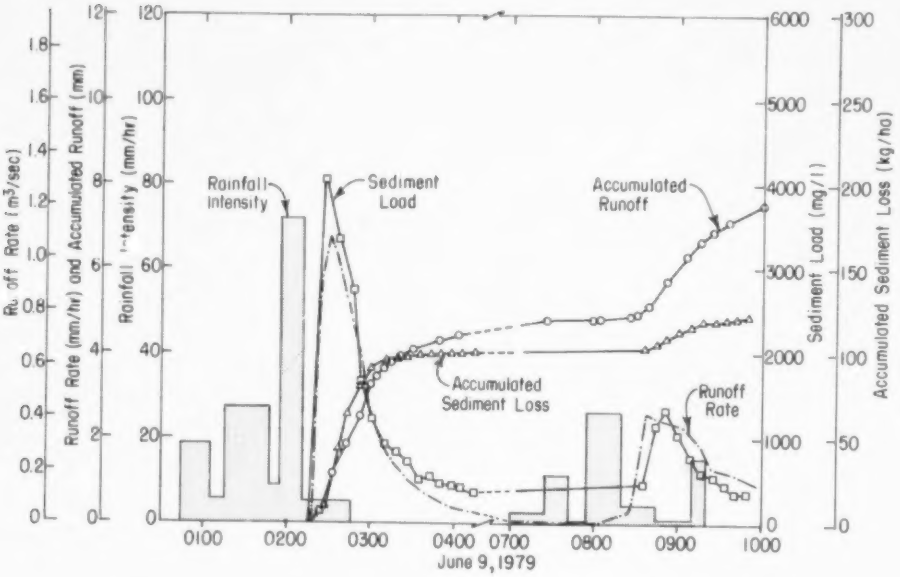

Figure 42. Hydrograph for event of June 9, 1979.

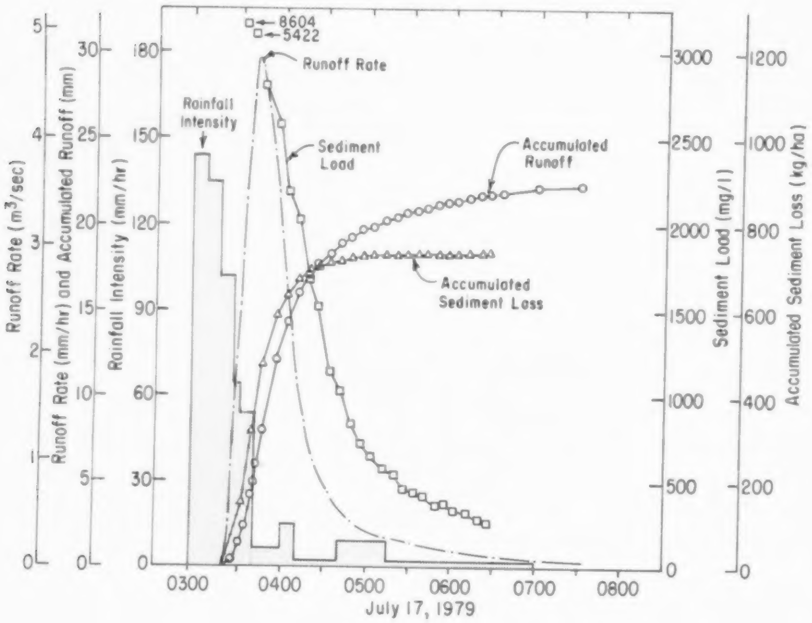

Figure 43. Hydrograph for event of July 17, 1979.

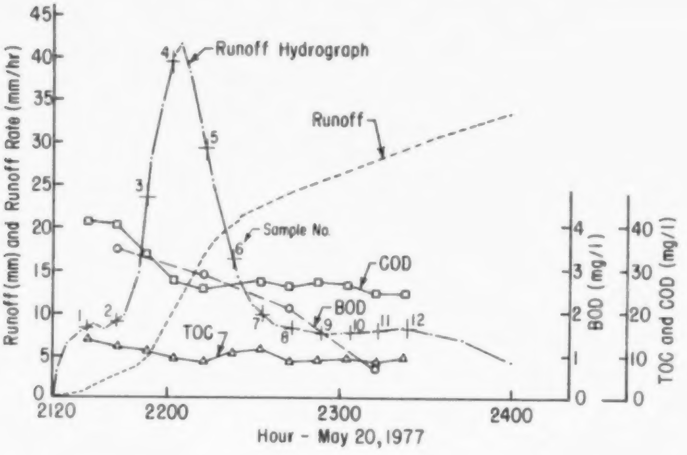

Figure 44. Variation of BOD, COD and TOC with runoff from event of May 20, 1977.

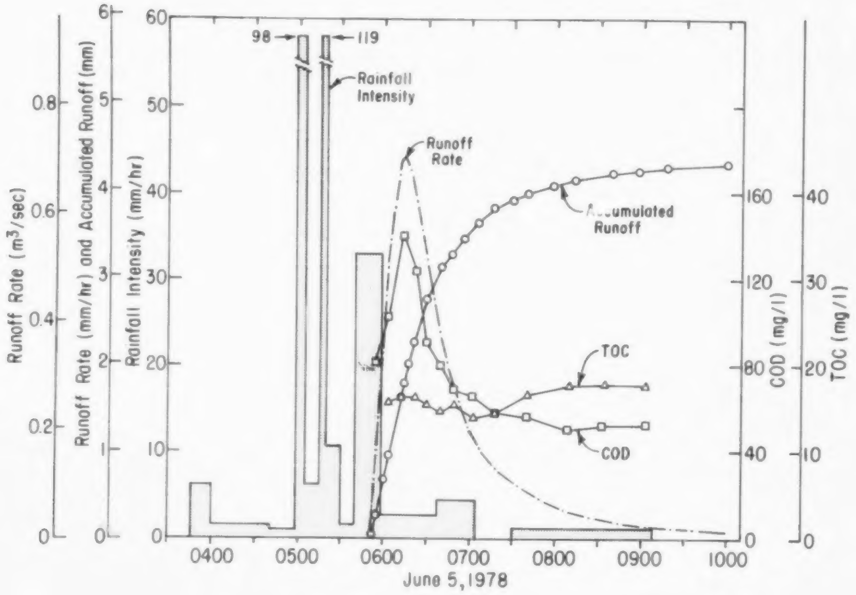

Figure 45. Variation of COD and TOC with runoff event of June 5, 1978.

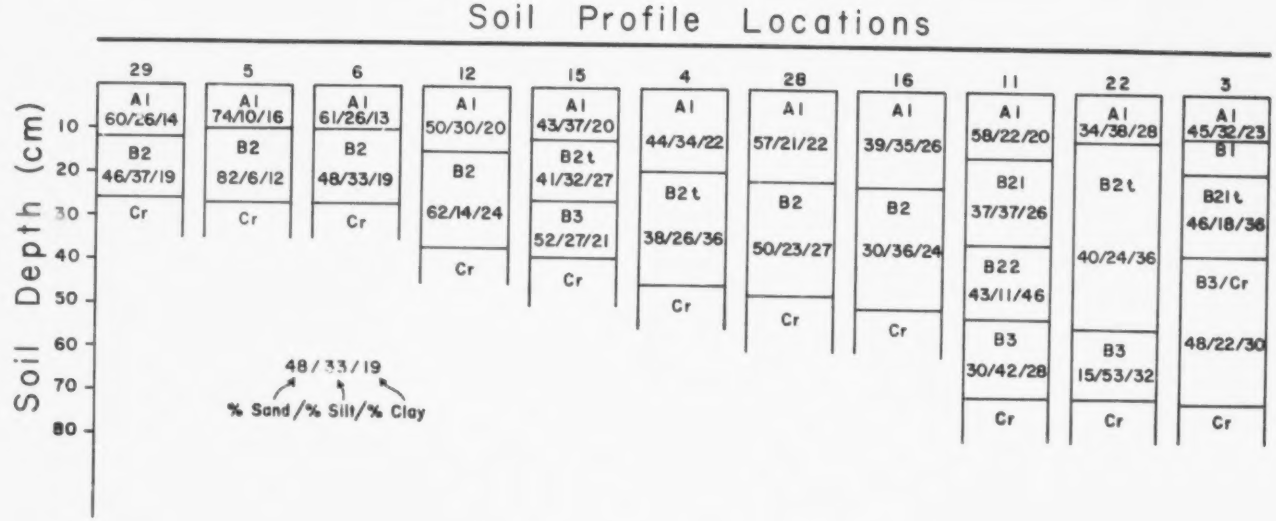
Soil Profile Locations
Soil Depth (cm)
10
20
30
40
50
60
70
80
29
A1
60/26/14
B2
46/37/19
Cr
5
A1
74/10/16
B2
82/6/12
Cr
6
A1
61/26/13
B2
48/33/19
Cr
12
A1
50/30/20
B2
62/14/24
Cr
15
A1
43/37/20
B2t
41/32/27
B3
52/27/21
Cr
4
A1
44/34/22
B2t
38/26/36
Cr
28
A1
57/21/22
B2
50/23/27
Cr
16
A1
39/35/26
B2
30/36/24
Cr
11
A1
58/22/20
B21
37/37/26
B22
43/11/46
B3
30/42/28
Cr
22
A1
34/38/28
B2t
40/24/36
B3
15/53/32
Cr
3
A1
45/32/23
B1
B21t
46/18/36
B3/Cr
48/22/30
Cr
48/33/19
% Sand/% Silt/% Clay

Figure 46. Soil profiles showing soil depth, horizon thickness and texture of the 29 sampling locations. Soil profiles for the ungrazed (U) locations inside exclosures and adjacent grazed (G) locations are also shown.

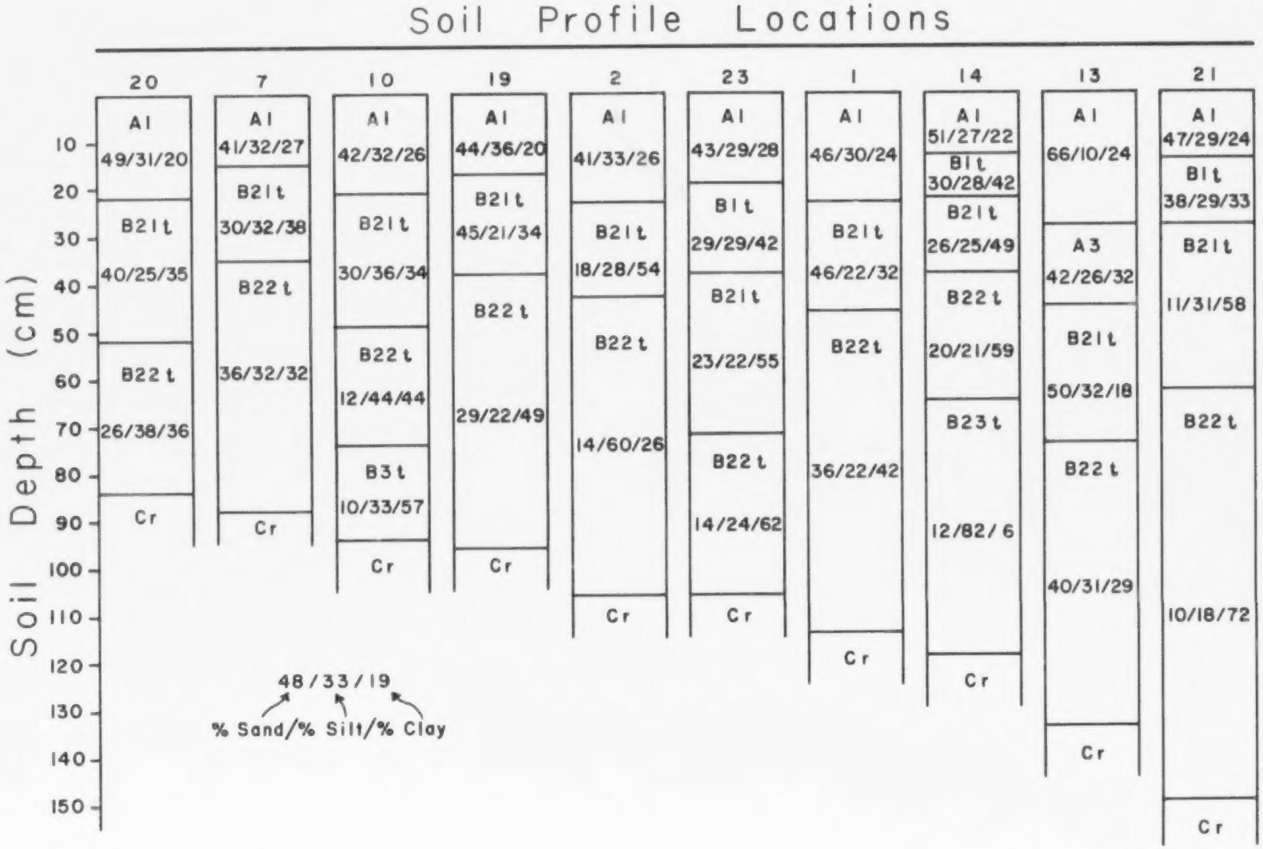

Figure 46. (Continued)

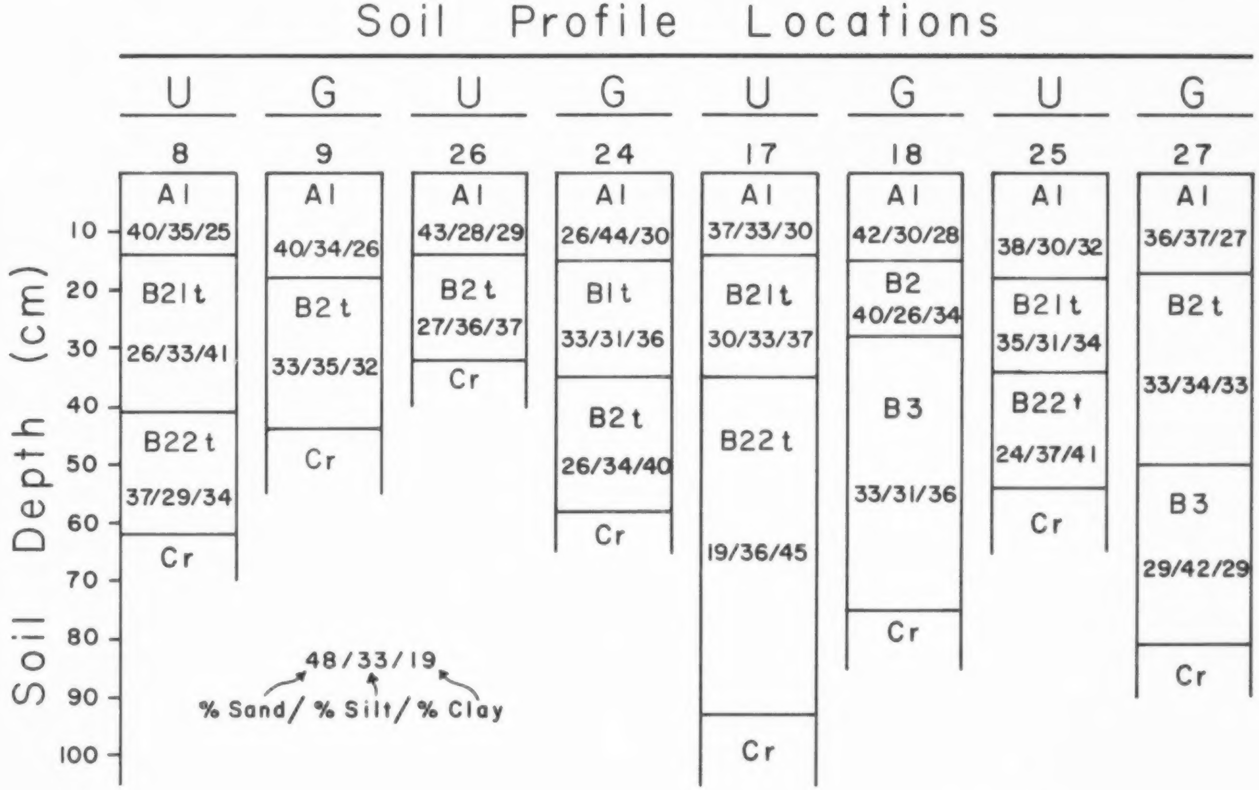
Soil Profile Locations
U
G
U
G
U
G
U
G
8
9
26
24
17
18
25
27
A1
40/35/25
B21t
26/33/41
B22t
37/29/34
Cr
A1
40/34/26
B2t
33/35/32
Cr
A1
43/28/29
B2t
27/36/37
Cr
A1
26/44/30
B1t
33/31/36
B2t
26/34/40
Cr
A1
37/33/30
B21t
30/33/37
B22t
19/36/45
Cr
A1
42/30/28
B2
40/26/34
B3
33/31/36
Cr
A1
38/30/32
B21t
35/31/34
B22t
24/37/41
Cr
A1
36/37/27
B2t
33/34/33
B3
29/42/29
Cr
Soil Depth (cm)
10
20
30
40
50
60
70
80
90
100
48/33/19
% Sand/ % Silt/ % Clay

Figure 46. (Continued)

The textures of B horizons varied more widely than did those of A horizons. The B2 horizons included loam, clay loam, silt loam, silt clay and silt clay loam.

Soil Chemical Composition

Soil Type

Soil samples were collected from the A horizon at all 29 locations averaged by soil type (Table 15). Soil acidity was in the neutral range (i.e., 6.1 to 7.0) for all soil types. Nitrate-N was less than 5 ppm for all soils. Ammonium-N ranged from 10 ppm to 22 ppm. Total phosphorus was relatively uniform except for an average of 438 ppm for Stephenville soils. Extractable phosphorus was low (i.e., 4 to 7 ppm) in all soils except Stephenville (16 ppm) and Darnell (17 ppm) soils. Both of these soils are shallow with a sandy loam A horizon. The concentrations of extractable cations (i.e., calcium, magnesium, potassium and sodium) were relatively uniform. The lowest values for calcium and magnesium concentrations were from Stephenville and Darnell soils.

Watershed Averages

Data from the 25 grazed locations represent a watershed average. Chemical composition averages and standard deviations for the samples collected periodically in 1976 and again in the fall of 1979 are as follows: 2.6 ± 0.53% organic matter, 0.11 ± 0.058% total (Kjeldahl) nitrogen, 6.0 ± 2.48 ppm extractable phosphorus, 335 ± 60 ppm extractable potassium, 2310 ± 580 ppm extractable calcium, 67 ± 37 ppm extractable sodium, 6.4 ± 4.8% total iron, 51 ± 30 ppm extractable iron and 290 ± 90 ppm extractable magnesium.

Slope Position

In March 1977 soil samples were collected from 60 locations randomly located throughout the watershed. Twenty transects from the top to the bottom of different slopes were used with soil samples collected at the upper, middle and lower slope positions. Chemical composition values by slope position are shown in Table 16.

Values for pH and total N were generally similar for all slope positions. Values for organic matter were slightly lower and values for extractable P, Ca and Mg were slightly higher at the middle slope position. Extractable K values increased slightly from the lower to upper slope positions. In general there were little differences in soil chemical values due to slope position.

Sampling Date

Soil samples collected between spring and fall seasons in 1976 showed a decrease in organic matter and a corresponding increase in total N in late May (Table 17). The changes in organic matter and total N occurred just after appreciable growth in plants began. There was no trend with season for pH.

TABLE 15. AVERAGE CHEMICAL COMPOSITION OF A HORIZON OF SOILS AT 29 PERMANENT SAMPLING LOCATIONS

Soil No.[1]	pH	B.I.[2]	Nitrogen (ppm)		Phosphorus (ppm)		Extractable Cations (ppm)			
			NO3-N	NH4-N	Total	Extr.	Ca	Mg	K	Na
1	6.3	7.1	5[3]	10	375	5	2300	660	340	90
2	6.1	6.9	5	22	375	17	2073	415	420	74
4	6.3	6.8	5	14	354	4	2130	530	398	143
5	6.4	7.0	5	11	344	5	2930	580	280	83
6	7.0	7.1	5	13	375	5	3300	440	360	77
7	6.3	7.0	5	13	363	5	2420	570	393	80
11	6.3	7.1	5	16	438	16	2250	375	445	73
12	6.2	7.0	5	14	313	7	2370	655	348	82
13	6.2	6.9	5	14	348	5	2610	640	384	80
15	6.2	6.9	5	17	396	7	2840	520	366	87

[1] Soil numbers correspond to soils described in the report.
[2] Buffer Index.
[3] All soil samples contained less than 5 ppm NO3-N.

TABLE 16. CHEMICAL COMPOSITION ($\bar{X}$ ± SD) OF A HORIZON OF SOILS AT DIFFERENT SLOPE POSITIONS ON GRAZED, TALLGRASS PRAIRIE WATERSHED IN NORTH CENTRAL OKLAHOMA, MARCH 1977

	Soil Chemical Component						
Slope Position	pH	Organic Matter (%)	Total N (%)	Extr. P (ppm)	Extr. K (ppm)	Extr. Ca (ppm)	Extr. Mg (ppm)
Upper							
$\bar{X}$	6.3	2.5	0.12	6.9	414	2447	59
sd	0.3	0.4	0.05	3.2	166	780	21
Middle							
$\bar{X}$	6.4	2.4	0.13	7.3	361	2532	64
sd	0.3	0.5	0.03	5.1	132	616	26
Lower							
$\bar{X}$	6.4	2.5	0.13	6.5	343	2469	60
sd	0.2	0.5	0.05	3.1	85	580	17
Average							
$\bar{X}$	6.4	2.5	0.13	6.9	373	2483	61
sd	0.3	0.5	0.05	3.8	128	659	21

Soil Water

Seasonal Trends

Total Soil Water--Total soil water in the soil profile during the 32-month sampling period varied from a low of about 90 mm in August of each year to a high of 200 mm in late May of 1977 and 1978 (Figure 47). Although soil water sampling did not begin until May of 1976, the relatively low amount of precipitation received in April and May of 1976 indicates the highest total soil water value in May, 1976 was probably about that shown on the first sampling date in Figure 47.

Sampling dates in Figure 47 include data from all 29 locations and data from six or seven locations adjusted by regression equations to predict the 29-location watershed average. Based on all these data we calculate the soil water storage capacity of the watershed soil to be about or slightly greater than 110 mm. Although no soils were totally depleted of soil water, it is unlikely natural evapotranspiration would reduce the total soil water in the soil much below the lowest figures shown.

The soil water depletion and recharge patterns were relatively consistent each of the three years. Soil water depletion was very rapid in late spring

TABLE 17. A HORIZON, SOIL FACTORS (X ± C.V.[%]) ON A NORTH CENTRAL OKLAHOMA TALLGRASS PRAIRIE WATERSHED GRAZED BY CATTLE, 1976

		Day							
Factor	Units	12 April	2 May	25 May	22 June	20 July	17 Aug.	14 Sept.	11 Oct.
PH	- - -	6.3±8	6.2±5	6.1±8	6.2±21	6.2±5	---[1]	6.1±5	6.1±5
Buffer Index	- - -	7.0±1	7.0±1	6.9±1	7.0±1	7.0±1	---	6.8±1	6.8±1
Organic Matter	%	2.74±21	2.88±18	1.87±30	2.40±23	2.59±15	2.73±26	2.75±18	2.68±21
Nitrogen									
Total	ppm	1200±25	1300±15	1700±24	950±37	1300±27	1600±28	1200±21	1300±23
NH_4	ppm	16±50	12±42	---	---	---	---	---	---
NO_3	ppm	3	3	---	---	---	---	---	---

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[1] Analysis not conducted.

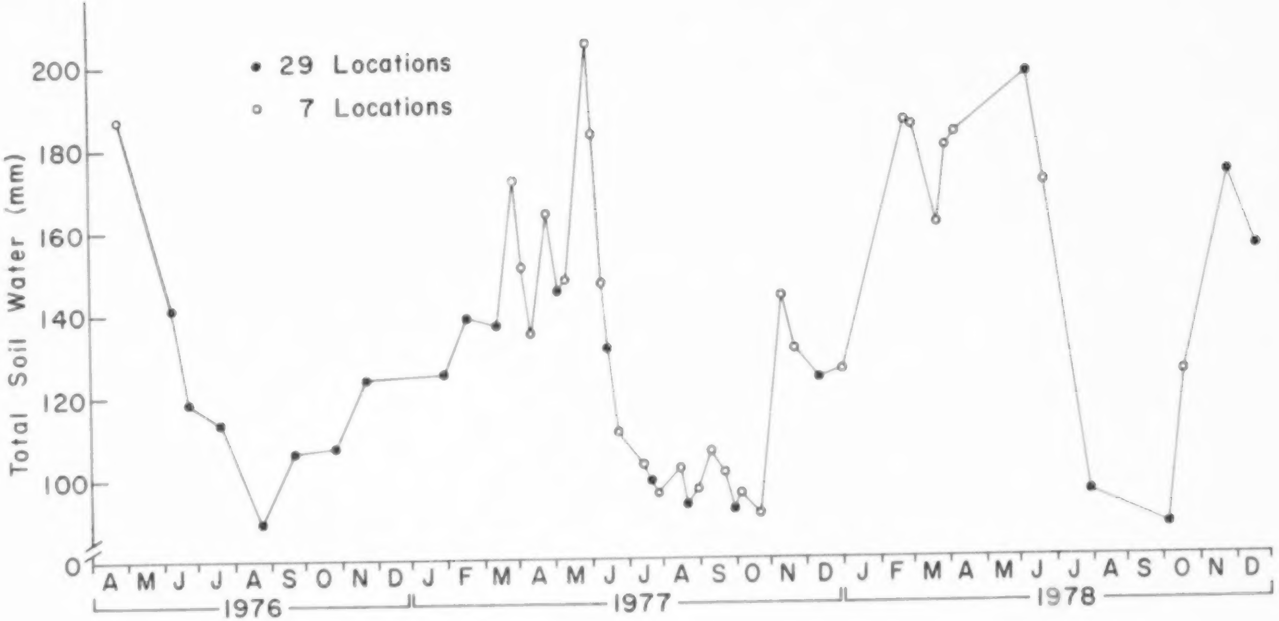

Figure 47. Total soil water content (mm) for watershed based on average of 29 locations or regression equation using seven representative locations.

during the period of most rapid plant growth. Based on the work by Powell et al. (1982) in the tallgrass prairie near El Reno, Oklahoma, most of the soil water depletion was due to transpiration rather than evaporation. Recharge occurred after the low point in August regardless of the amount of precipitation received. In general maximum depletion occurred in about three months whereas recharge occurred during the remaining nine months of the year.

Soil Water by Depth--The relationships between soil water in the upper 35 cm of the profile where the bulk of the root biomass is located, the soil water in the 35- to 120-cm layer of the watershed and the total soil water in the watershed soil (0-120 cm) are shown in Figure 48. Soil water values for the 35- to 120-cm layer are averages from soils with variable depths, many of which did not extend to 120 cm. The values of total soil water are therefore not averages, but sums of values for soil water in the 0- to 35-cm layer plus values for soil water in the 35- to 120-cm layer. The total soil water patterns in Figure 47 and Figure 48 differ because Figure 48 includes only values from dates when all 29 locations were sampled.

The upper 35 cms of soil averaged 52±18 mm of soil water, whereas the 35- to 120-cm layer averaged 71±14 mm of soil water or 19 mm more than the upper 35 cm of soil. Soil water recharge peaked earlier in the upper soil than in the subsoil during the winter of 1976-77. This is partly a reflection of percolation and partly a reflection of the greater soil water-holding capacity of the finer-textured subsoils. Unless soil water is sampled within two or three days after precipitation during the growing season, transportation rapidly depletes surface soil water. During the winter, surface soils lose soil water very slowly.

The effect of precipitation and soil water depletion on percent soil water at different depths in the soil profile is shown in Figure 49. In general percent soil water was greater and more consistent at lower depths. The A horizon, represented by soil water values at the 10-cm depth, had consistently less soil water than horizons at lower depths. Soil water at the 30-cm level was increased by light to moderate amounts of precipitation in the fall and winter and rapidly depleted by growing vegetation during the growing season.

The effect of significant root absorption and transpiration of soil water was also very evident at the deeper levels in the profile. Regardless of the amount of rainfall in early and mid summer, soil water was rapidly depleted between June and August. The similar percentages for soil water at peak recharge are indicative of similar clay contents in the B horizons of most soils on the watershed.

The average soil water contents (%) at different depths for each soil water sampling location are shown in Figures H-1, H-2, H-3, H-4, and H-5 in Appendix H.

Effect of Grazing

The average soil water contents at all depths in the soil profile were consistently greater where grazing was excluded during the study period than

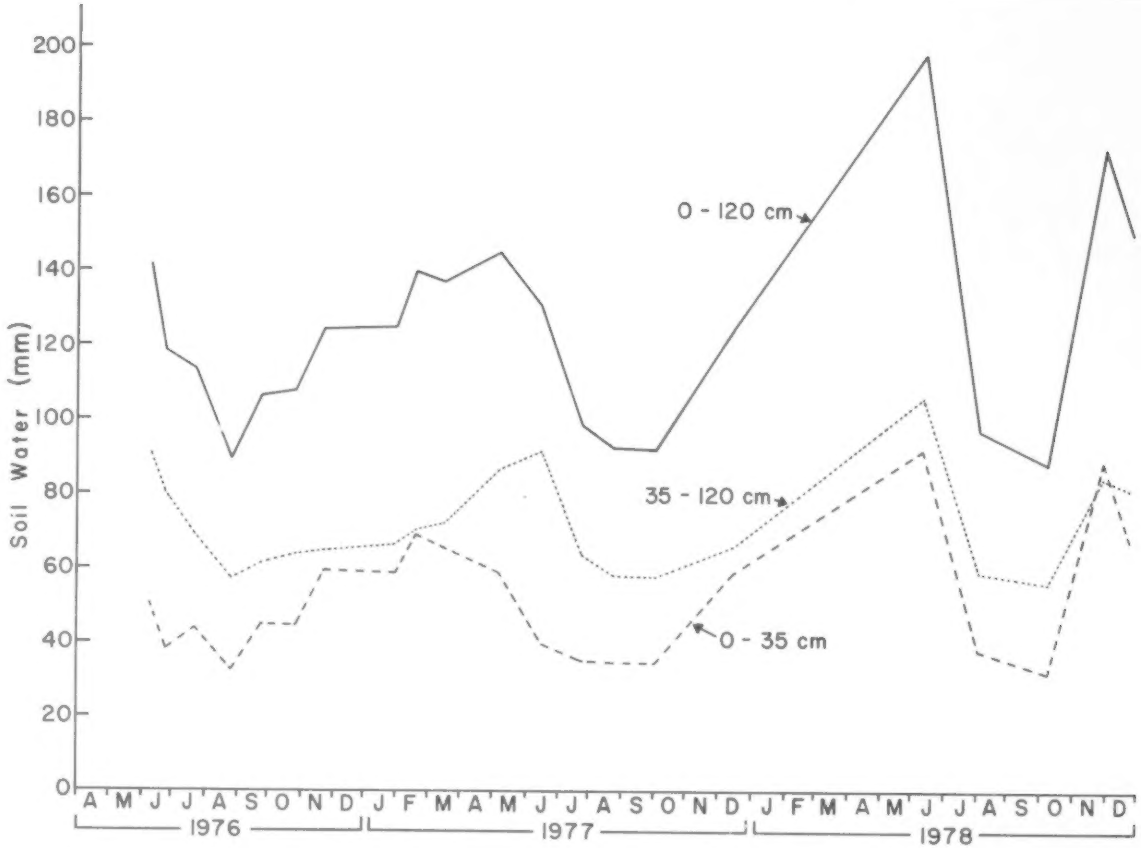

Figure 48. Average soil water content (mm) in upper 35-cm and lower 35-cm to 120-cm sections of watershed soil.

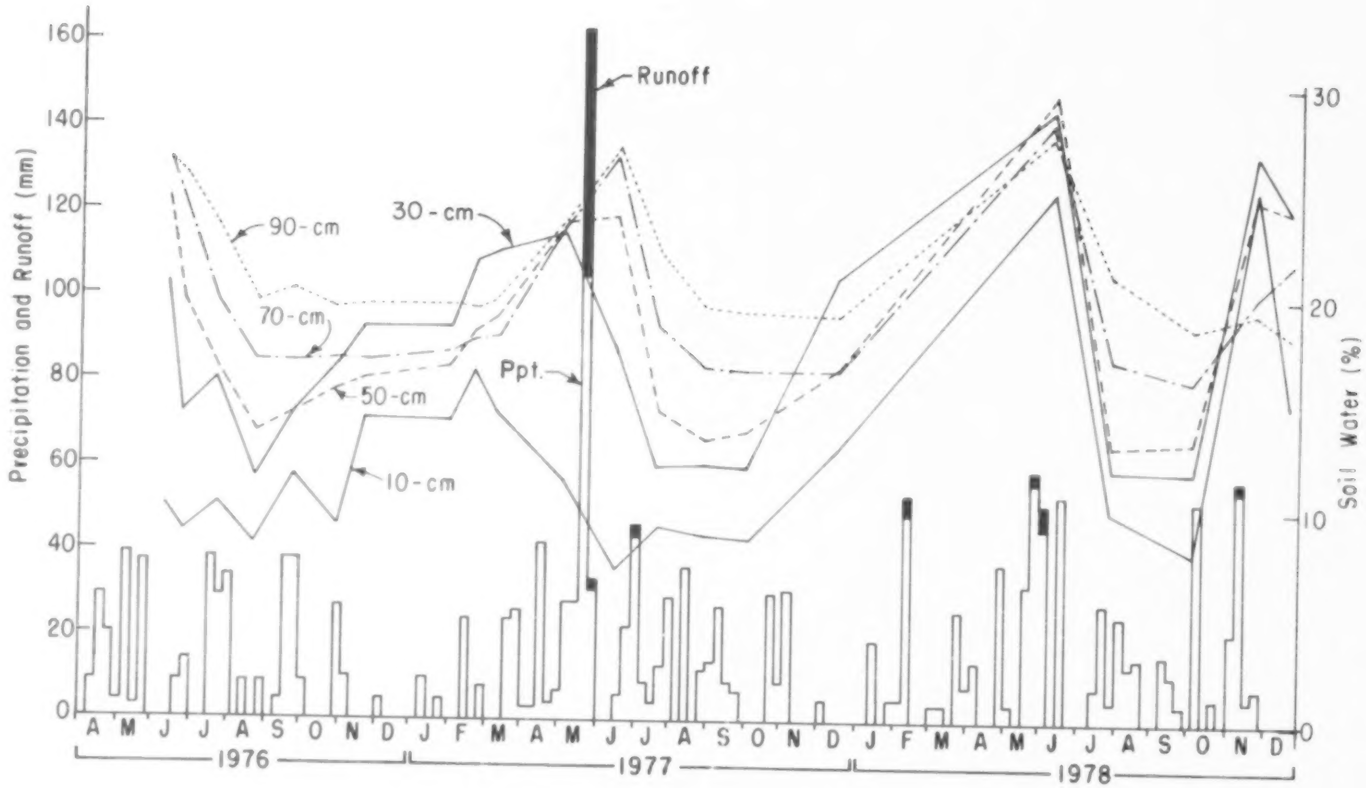

Figure 49. Change in soil water content (%) at different depths over time in relation to precipitation and runoff.

where grazing was allowed (Figure 50). Although soil characteristics (e.g., texture) for the paired soil water sampling locations differed slightly, the differences in soil water content were significant at the 0.01 level and appear to be due primarily to vegetation cover. No significant differences in surface soil bulk density were determined.

The average (i.e., 30 sampling dates between June 1976 and October 1978) standing, aboveground vegetation (kg DM/ha) for ungrazed and grazed areas were 3160 ± 750 and 1730 ± 830, respectively. The difference in herbaceous ground litter was greater than that shown for total ground litter because most of the dung was removed by hand from within the ungrazed exclosures. The average amount of dung removed from the exclosures was 640 kg DM/ha.

Although transpiration was undoubtedly greater on ungrazed areas because of greater average live biomass (1610 ± 730 kg DM/ha, ungrazed; 1050 ± 440 kg DM/ha, grazed), much greater insoak resulted in greater average soil water contents on ungrazed areas. This is indicated by the fact that soil water contents in the upper 15 cm of soil were not greatly different. Most of the differences were due to the water contents in the finer-textured B horizons. Greater root biomass in the ungrazed areas would cause greater soil water use from the A horizon where root concentrations are greater.

The actual values and differences in soil water contents may not be indicative of the watershed. All three exclosures were located on the upper elevation of the watershed in order to prevent unknown amounts of actual runoff from above the exclosures. There may be an optimum amount of aboveground plant biomass which was maintained or surpassed by grazed areas with more favorable site conditions. The eight locations indicated in Figure 50 were all on relatively shallow (i.e., 40 to 50 cm) upland soils. Additional research is needed to determine the vegetation-soil water relationships for all range sites.

Soil Water Use Rate

The rate of soil water use or loss from the soil due to evapotranspiration is shown in Figure 51. Soil water use rates were calculated as (precipitation - runoff - difference in total soil water in succeeding sampling dates) divided by the number of days between sampling dates. The data used to calculate soil water use are also presented in Appendix I. Several periods were combined in order to provide soil water use values significant at the 0.05 level of probability.

The rate of soil water use was related to soil water availability and vegetation growth. The total precipitation per period and the average soil water use rate per period are represented by the heights of the appropriate bars. Total soil water use per period is represented by the area (rate X number of days) of the bar for each period.

Only in the winter of 1977-78 was there a negative soil water use. Although precipitation insoak in the winter of 1977-78 was only slightly less than in the winter of 1976-77, the colder temperatures in the second winter reduced evaporation. Since soil water sampling was not consistent as to

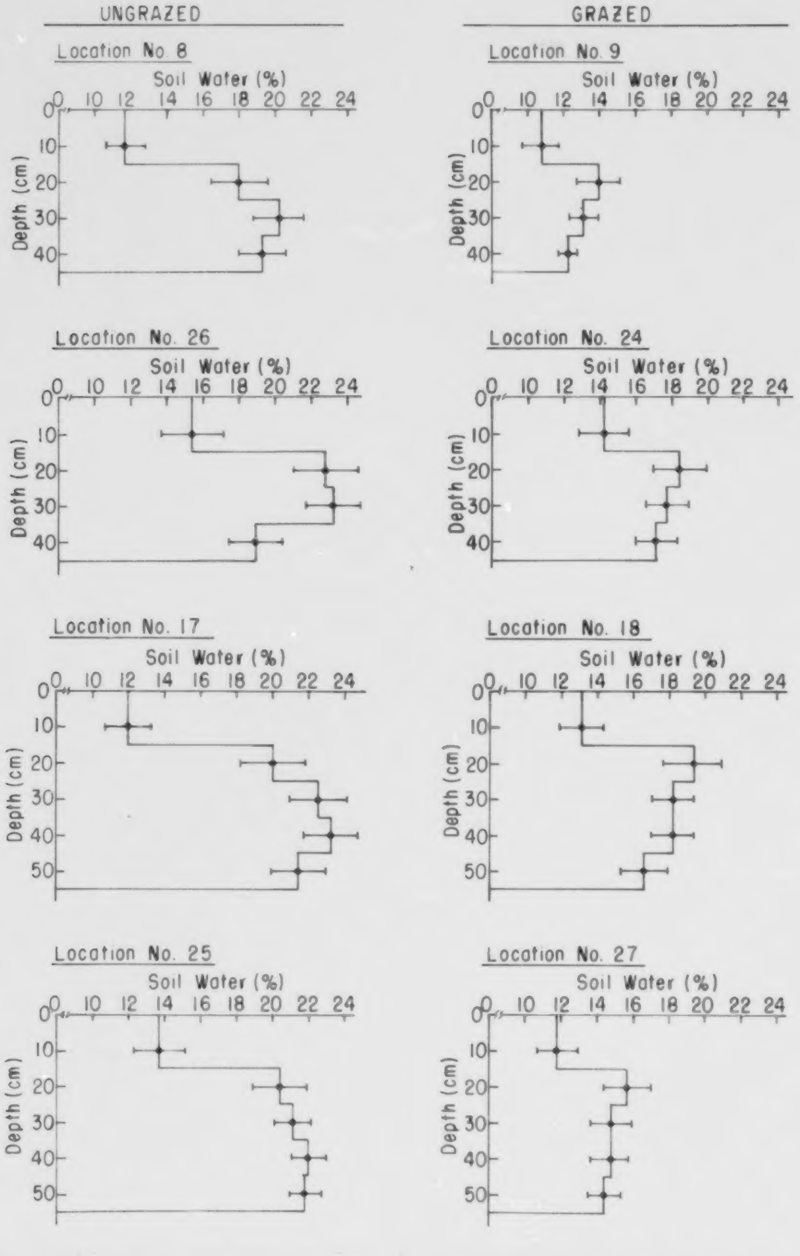

Figure 50. Average soil water content (%, X̄±SE) for four ungrazed and four adjacent, grazed locations on a tallgrass prairie watershed in North Central Oklahoma. Average of data from 21 collection dates between June 1976 and December 1978.

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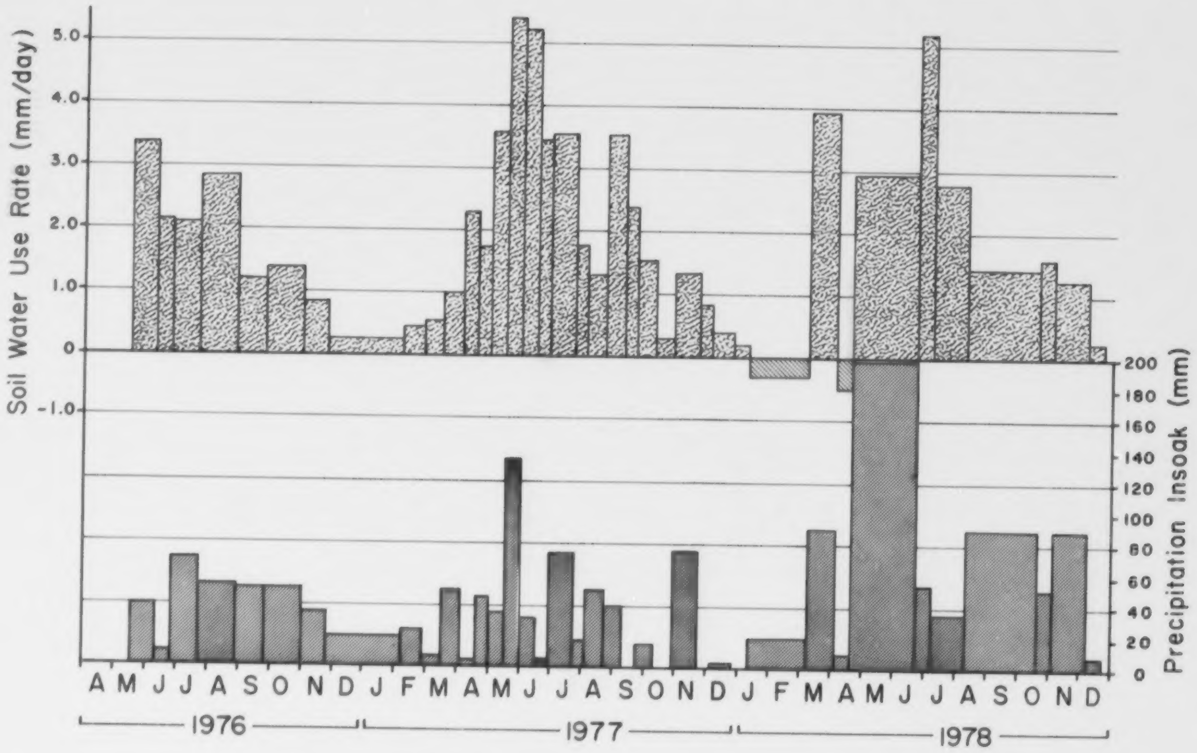

Figure 51. Soil water use rate (mm/day) in relation to precipitation and insoak (mm).

sampling date or sampling period length, it was not possible to make an exact comparison between soil water use rates; however, the values shown in Figure 51 are indicative of seasonal soil water use. The maximum values determined were above 5.0 mm/day in the May - June period in 1977 and in late June - early July of 1978. No doubt the use rates during some periods of May and June of 1978 were also greater than 5.0 mm/day.

The high use rate of 4.0 mm/day in March 1978 was greater than expected, but apparently was the result of warm temperatures and earlier and greater growth of cool season annual grasses. The negative use rate in April 1978 is somewhat misleading since soil water sampling occurred soon after an early April rain added more insoak than was depleted in March. Consequently, soil water use rate values during isolated short periods can lead to erroneous interpretations.

In general the soil water use rates shown in Figure 51 appear to be more realistic measures of evapotranspiration than pan evaporation or any other parameter that does not consider temperature, available soil water or water use by the actively growing species present at a particular time in the year. Soil water content indicates the soil water in the soil, but does not reflect the rate of evapotranspiration.

VEGETATION

Plant Biomass

The average ($\bar{X}$±SE) GROUND LITTER, STANDING DEAD and LIVE herbaceous vegetation (kg/ha, oven-dry) on the watershed are shown in Figure 52. Actual values ($\bar{X}$, SE) are shown in Appendix J. GROUND LITTER values were most variable, both within a single sampling date and between sampling dates. In 1976 GROUND LITTER biomass increased to a high in late summer then decreased during the winter. Rainstorms in May have caused the significant decrease in GROUND LITTER in September 1976, November 1977 and February 1978. Although runoff through the wier was not frequent, intense rain storms of short duration often moved recently deposited GROUND LITTER on steep slopes and ridgetops down to lower slopes where it was accumulated. Greater amounts of STANDING vegetation on the lower slopes acted as a barrier to overland flow of runoff water and GROUND LITTER. GROUND LITTER was generally least in early spring after winter decomposition. The relatively low GROUND LITTER biomass in the summer of 1977 was apparently the result of the large amount of runoff (60 mm) and the dung removal from sampling areas in May 1977. The average GROUND LITTER biomass during the study period was 2070 ± 2270 kg/ha. The standard error of the mean was 100 kg/ha.

STANDING DEAD biomass was more consistent than GROUND LITTER both within a single sampling date and between sampling dates. STANDING DEAD biomass was least in early spring and greatest in early winter. STANDING DEAD biomass was less in 1977 and 1978 because of reduced LIVE plant biomass in 1976 and 1977, respectively. Reduced plant production and consistent stocking rates yield a greater grazing pressure and reduced grazing residue. The average STANDING DEAD biomass during the study period was 1100 ± 850 kg/ha, with a standard error of 40 kg/ha.

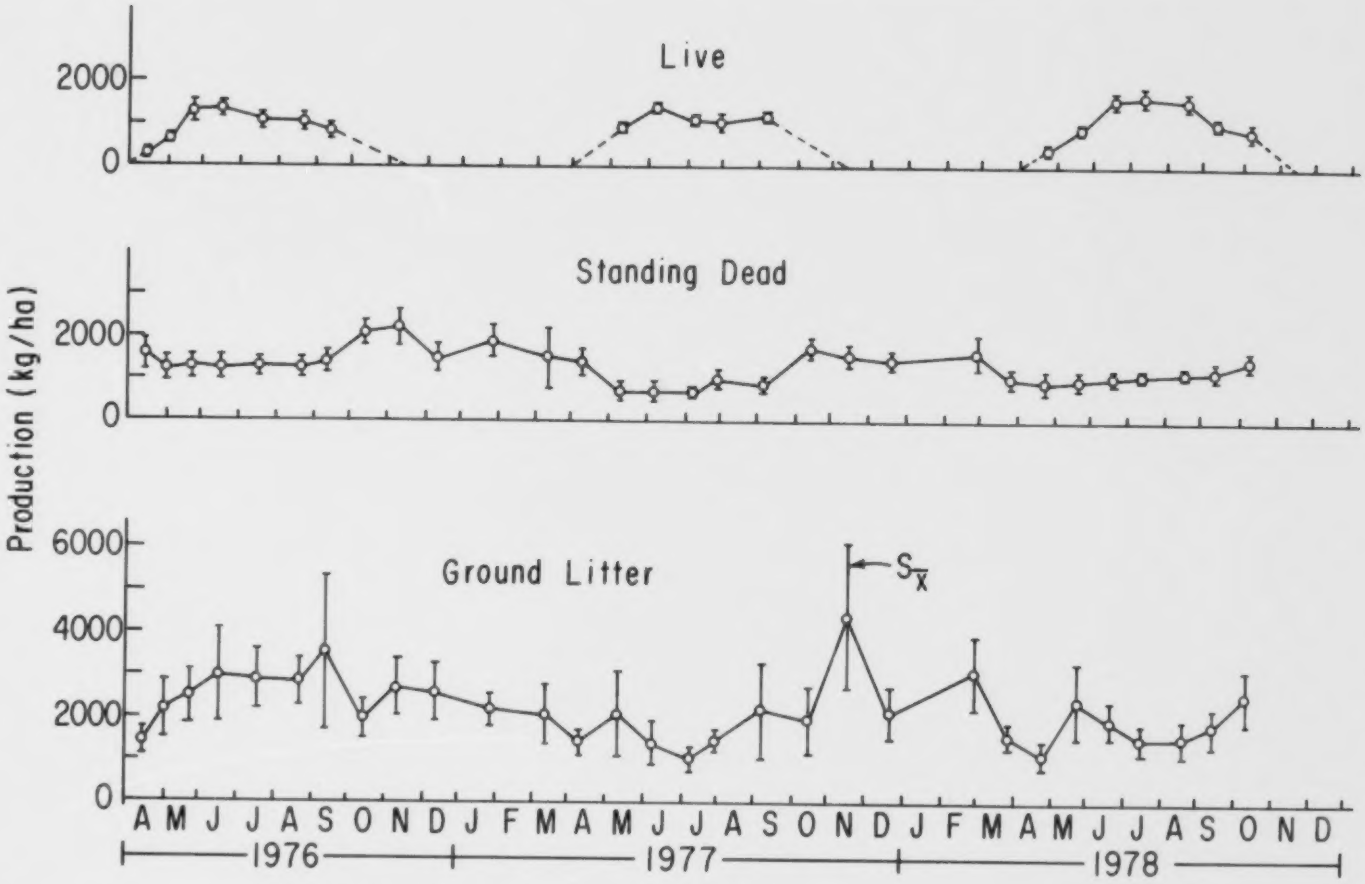

Figure 52. Average ($\bar{X}$±SE) GROUND LITTER, STANDING DEAD and LIVE herbaceous vegetation (kg/ha, oven-dry) on a tallgrass prairie watershed grazed by cattle in North Central Oklahoma.

STANDING DEAD plants act as a retardant to overland flow and increase insoak. Therefore, on grazed watersheds rangeland managers should try to determine and maintain the optimum amount of STANDING DEAD biomass to mimimize movement of dung and GROUND LITTER by overland flow. Although plants are least susceptible to grazing during their dormant season, excessive removal of STANDING DEAD vegetation increases the likelihood of undecomposed and accumulated dung moving into stream channels. In addition, work by Powell et al. (1982) shows that absolute minimum temperatures in January, accentuated by minimum STANDING DEAD and GROUND LITTER mulch, are negatively related to production and forage quality.

LIVE plant biomass was less in 1976 and 1977 than in 1978. Peak production was 1420 ± 550 kg/ha in mid-June 1976, 1440 ± 460 kg/ha in early June 1977 and 1630 ± 620 kg/ha in mid August 1978. Summer rains in 1977 caused a second peak production in early September. Summer rains in 1978 maintained peak production from late June through mid August.

Other scientists report the period of peak production in the tallgrass prairie varies from June to August depending on species composition, site factors such as mulch and soil water content, and external factors such as fire and grazing intensity (Broyles 1978, Conant and Risser 1974, Kelting 1954, Smeins and Olsen 1970, Tomanek and Albertson 1957). In general production peaks later in the summer when tallgrasses dominate the stand and when soil water conditions and grazing intensity permit net assimilation to exceed abiotic losses and herbivore utilization. Powell et al. (1982) reported that average maximum temperature in July accounted for about half the variation in tallgrass prairie production over a 22-year study near Stillwater.

Peak Production

Species Classes

LIVE plant biomass (kg/ha, oven-dry) for different species classes during the growing seasons of 1976, 1977 and 1978 is shown in Figures 53, 54 and 55, respectively. The list of plant species found on the watershed is presented in Appendix K. Most plant species exhibit a definite period of maximum growth and peak production during a growing season. Soil water use is related to plant growth. Rapid soil water depletion by spring or cool season species can influence the soil water available for summer or warm season species.

Grazing distribution is also influenced by plant phenology since animals usually prefer to graze the tissue of rapidly growing plants. When plant species are site dependent, livestock grazing on different range sites varies with plant species present and their phenological stage.

The differences in growth patterns for different species classes under grazing conditions are evident in each of the three figures. Rainfall was relatively low in 1976 and 1977 compared to that in 1978. Production of tallgrasses and little bluestem peaked in June 1976 because of limited rainfall in May and June. Production of cool season grasses and spring and early summer forbs peaked in late May. Production of shortgrasses and late summer forbs peaked in August in response to July rains.

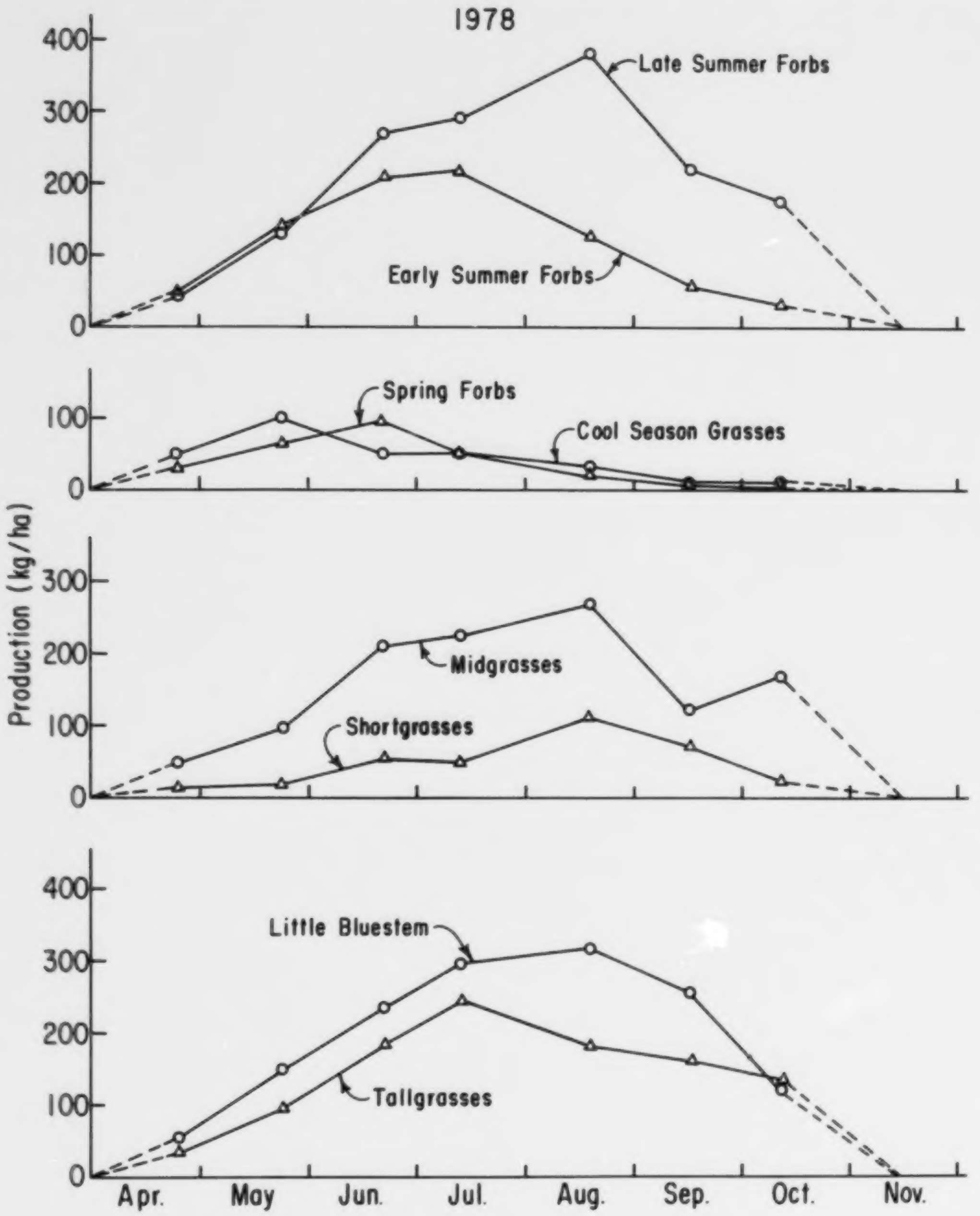

Figure 53. Dry matter production (kg/ha, oven-dry) of herbaceous species classes during the 1976 growing season on a tallgrass prairie watershed grazed by cattle in North Central Oklahoma.

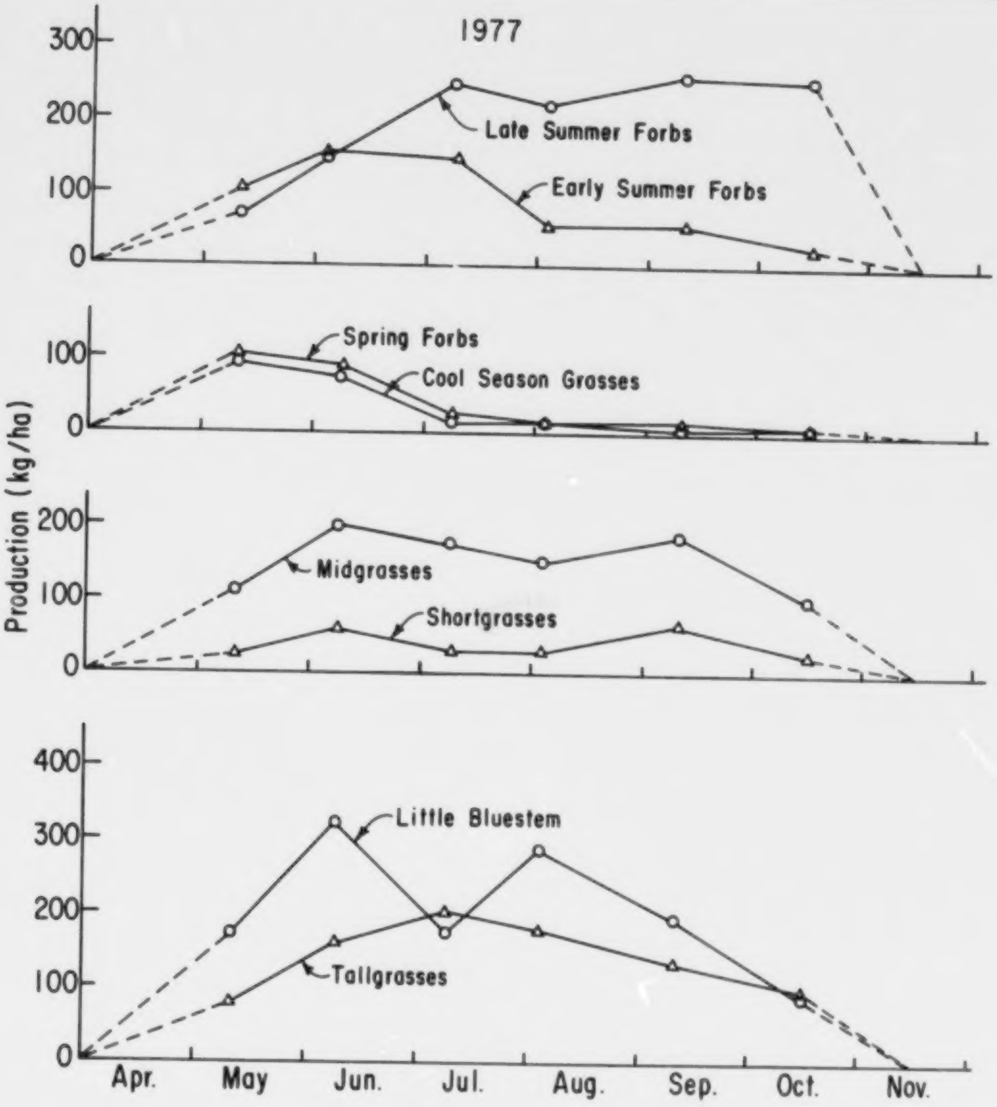

Figure 54. Dry matter production (kg/ha, oven-dry) of herbaceous species classes during the 1977 growing season on a tallgrass prairie watershed grazed by cattle in North Central Oklahoma.

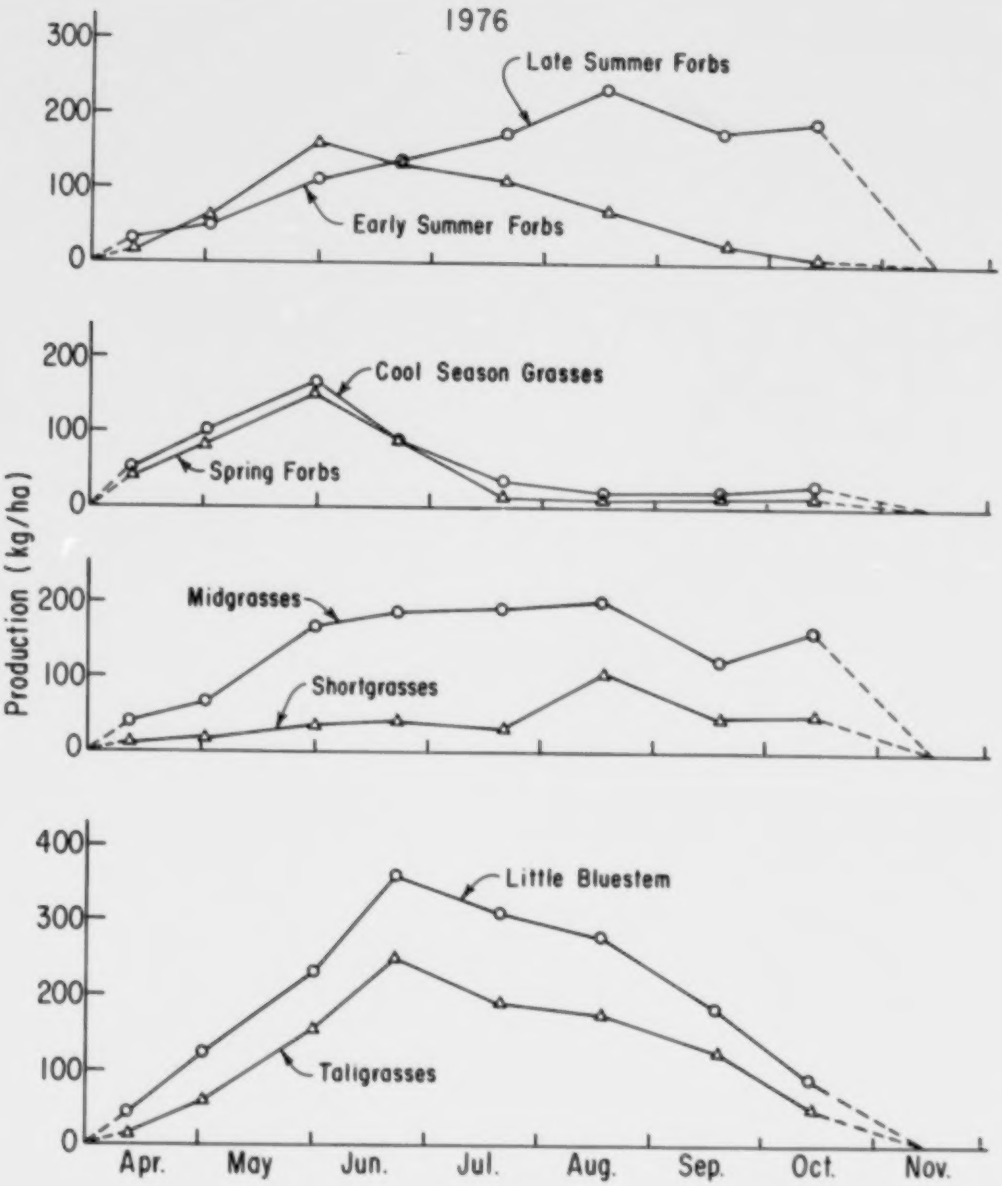

Figure 55. Dry matter production (kg/ha, oven-dry) of herbaceous species classes during the 1978 growing season on a tallgrass prairie watershed grazed by cattle in North Central Oklahoma.

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In 1977 production peaks for all species classes were somewhat different than those in 1976. The growth curves for most species classes were generally flatter than in 1976 with less pronounced peaks. The sharp decline in live little bluestem biomass between early June and early July is unexplained. The large amount of growth of leaf material in May may have exceeded the potential of the roots to maintain the water supply during the rapid soil water depletion in June. The second peak in little bluestem production in early August probably reflects a replenishment of surface soil water by late June and early July rains.

Little bluestem growth in the spring of 1978 was slower than in 1976 or 1977, but peak production was maintained over a longer period and later into the summer than during the two previous years. The relatively consistent growth pattern of tallgrasses reflects their deeper rooting depths. Production of shortgrassess, midgrasses, late summer forbs and little bluestem peaked in mid August at about the time soil water content was lowest. Apparently the rain in mid June 1978 did much to prolong the growth of warm season species.

These figures indicate growing conditions have a strong influence on growth curves of several species classes. Soil water influences plant growth and plant growth of species with different rooting patterns in turn influences soil water extraction.

Accumulative Production

Total LIVE rangeland plant biomass produced during a growing season is nearly always underestimated by sampling at only one time during the growing season. As discussed before, production for different species classes peaks at different times during the growing season.

Natural plant degradation and leaching of dry matter occurs even during the growing season. Therefore total LIVE plus current year's STANDING DEAD is not always an accurate measure of total growing season production.

Accumulative production or sum-of-the-peaks production is a more accurate measure of total range plant LIVE biomass production if the vegetation is composed of more than one species class. In this study, we divided existing species into eight different species classes. Spring forbs and cool season grasses could be combined into one species class based only on phenology. We choose to distinguish the two species classes because cool season grasses after death persist through the summer as standing dead. Most spring forbs after death become ground litter more rapidly than do cool season grasses.

In this study, the sum-of-the-peaks production was 24%, 14% and 17% greater than the greatest single peak production estimate in 1976, 1977 and 1978, respectively. With a more uniform rainfall distribution during the spring and summer, the difference is expected to be greater. The difference would also be greater when the range condition is higher because of the greater diversity of plant species with different phenologies.

Another factor to be considered in estimating total plant production on a grazed watershed is the amount consumed and trampled by grazing animals. Assuming an average utilization (ingestion plus trampling) figure of 12 kg dry matter per animal-unit-day from May through July and using the stocking density figures calculated, dry matter disappearance due to grazing was 410 kg/ha May through July, 1976, 400 kg/ha May through July, 1977 and 350 kg/ha May through September, 1978. These figures represent 30%, 30%, and 22% of the greatest peak LIVE biomass in 1976, 1977 and 1978, respectively. These exact amounts should not be added to accumulative production because part of the material utilized later in the summer was no doubt a part of the peak production contributed by species classes with early peak production. Utilization or dry matter disappearance due to grazing will be discussed in greater detail in the section of the report concerning utilization. In general, however, the addition of 30% to 50% greater production than shown in Figures 53, 54, and 55 would be valid when considering the relationships between plant production and soil water use.

Range Sites

Differences in plant species class biomass (kg/ha), composition (%) and selected site factors on loamy prairie and shallow prairie range sites are shown in Table 18. LIVE, STANDING DEAD and GROUND LITTER biomass were all greater on loamy prairie sites than on shallow prairie sites. Loamy prairie sites included the deeper soils which generally occurred at the lower slope positions, whereas shallow prairie sites included the soils on the upper slopes. Tallgrasses, little bluestem, late summer forbs and shrubs are all relatively deep-rooted and were more abundant on the deeper soils.

Grasses were of about the same proportion of total LIVE vegetation on both sites, but forbs comprised a higher proportion of LIVE vegetation on the shallow prairie sites. Shortgrasses were also much more abundant on shallow prairie sites.

Ground cover and A horizon soil water content were greater on the loamy prairie range sites. Surface soil temperature was greater on the shallow prairie range sites.

The claypan prairie, shallow savannah and sandy savannah range sites were not sampled with enough locations to warrant statistical comparisons. These three range sites occupied only 15% of the watershed, whereas loamy prairie range sites occupied 53% and shallow prairie 32% of the watershed.

From a watershed and livestock grazing management standpoint, a range site is a practical and fundamental unit of management. Site conditions influence plant production, species composition and, frequently, plant palatability. Consequently, range site conditions influence grazing preference. Grazing preference, in turn, can accentuate differences in site conditions, such as ground cover and species composition. An understanding of range site-grazing preference relationships is, therefore, essential if a watershed scientist is to accurately predict or effectively manipulate the effects of livestock grazing on runoff quantity and quality.

TABLE 18. PLANT SPECIES CLASS BIOMASS (KG/HA), COMPOSITION (%) AND SELECTED SITE FACTORS ON LOAMY AND SHALLOW PRAIRIE RANGE SITES ON A TALLGRASS PRAIRIE WATERSHED GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-78

Species Class	Biomass(kg/ha) Range Site			Composition(%) Range Site		
	Loamy	Shallow	P[1]	Loamy	Shallow	P
(19 Sampling Dates)						
LIVE	1205	965	*			
GRASSES	770	575	*	64.7	63.2	0.25
Tall	215	65	*	16.4	6.5	*
SCSC	275	160	*	22.7	16.2	*
Mid	170	160	0.63	14.4	18.3	*
Short	30	90	*	3.2	10.8	*
Cool	45	40	0.88	4.4	5.4	0.17
Other	40	55	*	3.8	6.0	*
FORBS	335	350	0.54	29.5	35.1	*
Spring	40	60	*	4.7	6.6	*
Early Summer	105	130	0.13	9.1	12.2	*
Late Summer	190	160	0.07	15.8	16.4	0.54
SHRUBS	100	35	*	5.9	1.9	*
LIVE (%)				49.7	56.2	*
(31 Sampling Dates)						
STANDING DEAD	1295	760	*			
GROUND LITTER	1925[2]	1485[3]	*			
ABOVEGROUND PHYTOMASS[4]	4410	3210	*			
GROUND COVER (%)	89.1	80.7	*			
SOIL WATER (A horizon) (%)	9.2	8.0	0.08			
SOIL TEMP. (C)	23.4	25.4	*			

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[1] Probability level (* = P 0.05).

[2] Includes dung on first four sampling dates.

[3] Includes dung on all sampling dates.

[4] LIVE + DEAD + GROUND LITTER.

Grazing Effects

The average LIVE and STANDING DEAD plant biomass (kg/ha, oven-dry) inside (ungrazed) and outside (grazed) three, 0.5 ha cattle exclosures during the study period is shown in Figure 56. In general growth patterns for LIVE vegetation inside and outside the exclosures were similar. Therefore, although grazing reduced the amount of LIVE vegetation, residue grazing did not significantly alter the growth pattern or period of peak standing production except during the dry summer period in 1976. At this time grazing tended to flatten the growth curve.

Differences between ungrazed and grazed STANDING DEAD litter were smaller in 1976, the first year exclosures were in effect, than in the two following years. STANDING DEAD litter biomass in any year is largely the result of the previous year's production and to a lesser extent, the current year's DEAD from cool season annual grasses and forbs.

The sharp increase of STANDING DEAD in the fall of 1976 and gradual decline until late summer of 1977 was similar inside and outside the exclosures. Differences in STANDING DEAD were greatest in 1978 and probably reflects the beginning of significant accumulated effects of grazing.

The utilization study determined that cattle consumed a significant amount of STANDING DEAD during all seasons. The average STANDING DEAD in the diet was about 55% during the 30-month sampling period and exceeded 20% even during the growing season when LIVE forage was relatively abundant.

The STANDING DEAD was reduced to its lowest amount in March, 1978 outside the exclosures and only gradually increased during the growing season. This was in contrast to the rapid decline in STANDING DEAD in ungrazed areas between March and late June and the rapid increase between late June and the fall. Apparently natural weather conditions converted much of the ungrazed STANDING DEAD to GROUND LITTER in the spring of 1978. The rapid increase in ungrazed STANDING DEAD after June indicates the death of many plants and plant parts when plants mature or conditions become less favorable for growth.

Differences in average species class biomass (kg/ha) and composition in ungrazed and adjacent grazed areas is shown in Table 19. Because of the large number of sampling periods (i.e., 19 during the growing season and 12 during the dormant season) and the accumulative effects of grazing, most of the differences were significant at the 0.05 or less level. Shortgrasses maintained production under relatively xeric conditions on the upper slopes where the exclosures were located. Grazing pressure near one of the exclosures was heavy and shortgrasses are more resistant to heavy grazing pressure than most other species in the tallgrass prairie. Spring forbs and "other" grasses were also as abundant on grazed areas as inside the exclosures. Warmer soils on grazed areas in the spring increased spring forb production. Many of the "other" grases were less palatable, "increaser" species.

The changes in percent composition shows that grazing on the upper slopes tends to reduce tallgrasses and little bluestem and increase those species which are more resistant to grazing due to morphological characteristics or

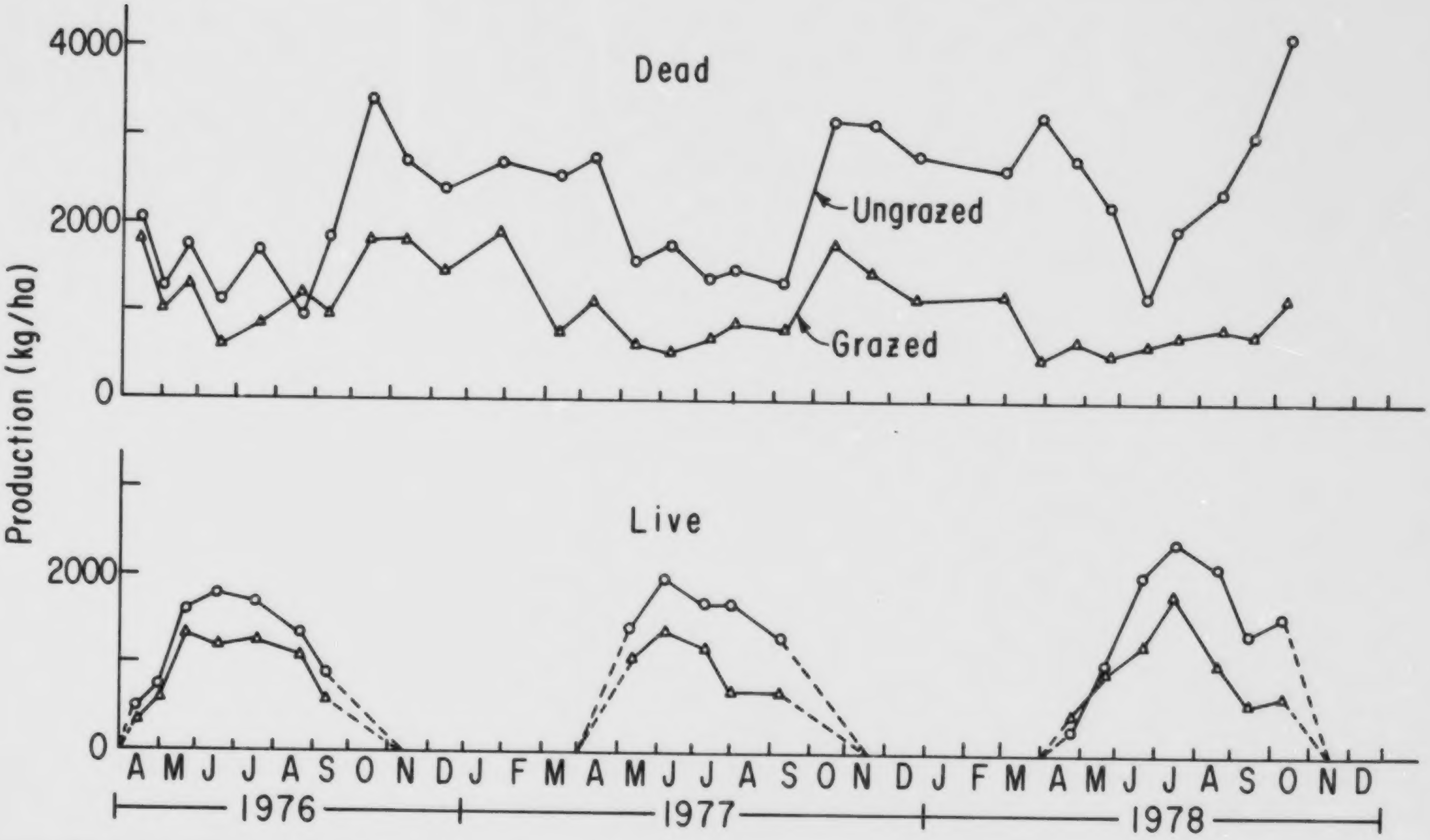

Figure 56. Average LIVE and STANDING DEAD plant biomass (kg//ha, oven-dry) inside (ungrazed) and outside (grazed) three, 0.5-ha exclosures on a tallgrass prairie watershed grazed by cattle in North Central Oklahoma.

TABLE 19. COMPARISON OF AVERAGE (3 PAIRED SAMPLES) PLANT SPECIES CLASS BIOMASS (KG/HA, OVEN-DRY), COMPOSITION (%), AND SELECTED OTHER FACTORS INSIDE (UNGRAZED) AND OUTSIDE (GRAZED) THREE, 0.5 HA EXCLOSURES ON A TALLGRASS PRAIRIE WATERSHED GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-78

Species Class	Biomass (kg/ha)				Composition (%)			
	Ungr.	Grazed	Diff.[1]	P[2]	Ungr.	Grazed	Diff.	P
(19 Sampling Dates)								
TOTAL LIVE	1480	1030	-450	0.01				
GRASSES	1020	660	-360	0.01	70.0	64.8	-5.2	0.04
Tall	225	100	-125	0.01	14.0	9.1	-4.9	0.01
Little bluestem	420	220	-200	0.01	28.5	21.3	-7.2	0.01
Mid	235	190	-45	0.20	17.2	17.9	+0.7	0.66
Short	55	85	+30	0.15	4.1	8.7	+4.6	0.01
Cool Season	55	30	-15	0.04	4.6	3.4	-1.2	0.28
Other	25	40	+15	0.04	1.9	4.4	+2.5	0.01
FORBS	450	345	-105	0.05	29.3	32.9	+3.6	0.15
Spring	45	45	0	0.75	3.8	5.7	+1.9	0.12
Early Summer	225	165	-60	0.18	13.8	13.7	-0.1	0.97
Late Summer	185	130	-55	0.04	11.9	13.6	+1.7	0.24
SHRUBS	10	25	+15	0.08	0.7	2.3	+1.6	0.05
% LIVE					43.9	52.5	+8.6	0.01
(31 Sampling Dates)								
STANDING DEAD	2390	1190	-1200	0.01				
GROUND LITTER	2040[3]	1750[4]	-290	0.16				
ABOVEGROUND PHYTOMASS[5]	5620	3520	-2100	0.01				
GROUND COVER (%)	96.2	86.0	-10.2	0.01				
SOIL WATER (%, A Horizon)	11.1	10.7	-0.4	0.71				
SOIL TEMP. (C)	17.9	19.9	+2.0	0.18				

[1] Grazed - Ungrazed.

[2] Probability level.

[3] Includes dung on first four sampling dates.

[4] Includes dung on all sampling dates.

[5] LIVE + STANDING DEAD + GROUND LITTER.

lower palatability. Many of the late summer forbs were low in palatability. The greater biomass and percent composition of shrubs outside exclosures was contradictory to what was observed. Most of the plants of shrub species were observed to be grazed near the exclosures. Certain species, such as *Ulmus americana*, definitely showed a hedged effect (Figure 57), and other shrub species, such as *Rhus* spp., normally considered to be unpalatable, showed evidence of browsing.

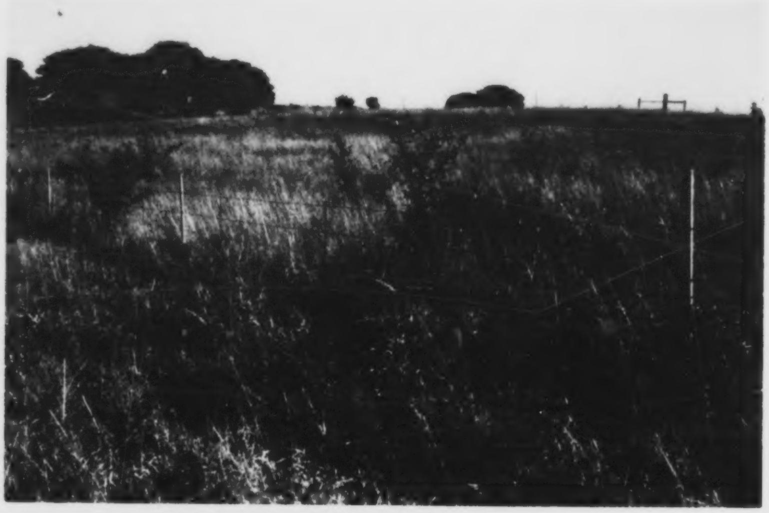

Figure 57. Effect on browsing on shrubs outside exclosure.

Differences in GROUND LITTER were small because all dung was removed from within exclosures in the summer of 1976. Therefore although herbaceous GROUND LITTER was much less outside exclosures, the dung deposited in grazed areas increased the total GROUND LITTER recorded. Including dung in the total GROUND LITTER is a realistic assessment of energy flow and nutrient cycling since much of the forage consumed by grazing animals passes through the animals and remains on the watershed.

Ground cover was reduced by grazing on the upper slopes and more bare ground provided greater opportunity for establishment of cool season annual grasses and other species of a lower successional level. Reduced ground cover also increases the effect of raindrop splash and soil particle displacement. Because of concentrated grazing on soils of the upper slopes where the exclosures were located, the ground cover value shown in Table 19 was much less than the average over the whole watershed.

Soil water content in the A horizon was similar in the grazed and ungrazed areas. This does not reflect the differences in total soil water. Greater root biomass (inferred from greater live vegetation biomass) in ungrazed areas would cause greater transpiration loss. However, greater ground cover in ungrazed grass would conversely reduce evaporation loss. Infiltration rates were not determined and such data would help to interpret the soil water budget in the different areas.

It should be pointed out that the values for TOTAL LIVE in Table 19 reflect the average LIVE vegetation at a point in time. These values do not reflect total vegetation produced in the grazed areas. The utilization study using small cages in the grazed locations near the exclosures showed that an average of 425 kg/ha was removed by grazing animals. Therefore, adding the amount of LIVE vegetation utilized (425 kg/ha) to the average LIVE grazing residue (1030 kg/ha) indicates total production (1455 kg/ha) on grazed areas near the exclosures was about the same as that (1480 kg/ha) in ungrazed areas. Since the tallgrass prairie evolved under grazing, it should not be unexpected that properly grazed areas are as productive as ungrazed areas.

Soil temperature values in grazed areas averaged 2.0 C higher than in ungrazed areas, but the magnitude of differences was not consistent (P 0.18). Differences appeared to be related to grazing pressure. Grazed area temperatures were 0.6 C, 1.5 C and 2.6 C higher on the light, moderate and heavy grazed areas, respectively. Those areas with the greatest differences in ground cover and standing vegetation had the greatest differences in soil temperatures.

Site Factors, Species Frequency and Biomass

Species Frequency (Late Winter, 1976)

Slope length varied from 82 to 158 m and slope percent ranged from 1 to 7% for the 20 transects. Although the same major species were found on all slope positions indicating that many common species have a broad ecological amplitude, their frequency of occurrence varied by slope position, aspect, and soil type.

Slope position--The number of grass species found on different slope positions was similar; however, desirable tallgrasses (*Andropogon gerardi*, *Sorghastrum nutans*, and *Panicum virgatum*) were least common on upper slope positions (Table 20). Tallgrasses were three times more common on lower slopes than upper slopes. *Sorghastrum nutans* (SONU) was twice as common as *Andropogon gerardi* (ANGE) on lower and mid slopes, but all three desirable tallgrasses had similar frequencies on upper slope positions. *Andropogon virginicus* (ANVI) was found in 10% of the lower slope plots and was most common on the deeper soils.

Schizachyrium scoparium (SCSC), the most common species, occurred at 86% of all sampling locations. SCSC and *Panicum oligosanthes* (PAOL) were found more frequently on lower slopes and least frequently on upper slopes (Table 20). However, SCSC was present in 73% of the upper slope plots while PAOL frequency decreased to 38% in upper slope plots. The third midgrass, *Bouteloua curtipendula* (BOCU), was similar to shortgrasses in frequency on slope positions and changed little in relation to slope position. *Carex* spp. were present in about half of the quadrats sampled but *Carex* frequency did not change with slope position.

TABLE 20. FREQUENCY OF OCCURRENCE (%) FOR SELECTED SPECIES AND SPECIES CLASSES ON DIFFERENT SLOPE POSITIONS

Species Class and Species	Slope Position			
	Lower	Mid	Upper	Prob.[1]
GRASSES				
Tallgrasses				
Desirable tallgrasses[2]	63	49	19	0.01
Andropogon gerardi	21	13	7	0.12
Panicum virgatum	19	22	7	0.21
Sorghastrum nutans	45	21	8	0.01
Andropogon virginicus	10	3	0	0.19
Midgrasses				
Schizachyrium scoparium	98	87	73	0.07
Panicum oligosanthes	77	54	38	0.01
Bouteloua curtipendula	33	50	58	0.14
Carex spp.	50	43	41	0.68
Shortgrasses				
Bouteloua hirsuta	14	31	46	0.03
Bouteloua gracilis	8	18	23	0.10
Aristida oligantha	43	42	68	0.06
Aristida spp. (perennial)	12	14	13	0.91
FORBS				
Ambrosia psilostachya	65	57	63	0.86
Artemisia ludoviciana	20	4	6	0.01
Xanthocephalum dracunculoides	10	30	36	0.05
Diversity Index[3]	7	7	7	0.78

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[1] Probability that differences in frequency of species among slope positions are due to chance.

[2] These species are the most desirable for livestock grazing and include only *Andropogon gerardi*, *Panicum virgatum*, *Sorghastrum nutans*.

[3] Average number of different species in sampling locations at each slope position.

Shortgrasses were nearly as abundant on upper slopes as tallgrasses were on lower slopes. Frequency of *Bouteloua hirsuta* (BOHI) was nearly twice that of *Bouteloua gracilis* (BOGR) on all slope positions. BOHI and BOGR were both more abundant on upper slopes than on lower slopes. *Aristida oligantha* (AROL) was also more common on upper slopes which had more xeric soils and more plant disturbance (e.g., consumption of herbage and animal trampling). Other *Aristida* species (*Aristida longiseta*, A. *purpurascens*) were not common at any slope position.

The average number of forb species per quadrat was the same at all slope positions. *Ambrosia psilostachya* (AMPS), the most common forb, was affected very little by slope position. In general *Artemisia ludoviciana* (ARLU) was associated with tallgrasses and deeper soils. *Xanthocephalum dracunculoides* (XADR) was frequently found in areas disturbed by grazing, and was three times more abundant on mid and upper slopes than on lower slopes. The frequency of occurrence of XADR was inverse to that of ARLU.

A species diversity index indicated that there was no difference in the number of species found in samples along slope positions although species composition was diverse. STANDING LITTER, TOTAL LITTER (STANDING and GROUND) and STANDING LITTER to GROUND LITTER ratio were highest on lower slope positions where tallgrasses were more abundant and lowest on upper slope positions (Figure 58).

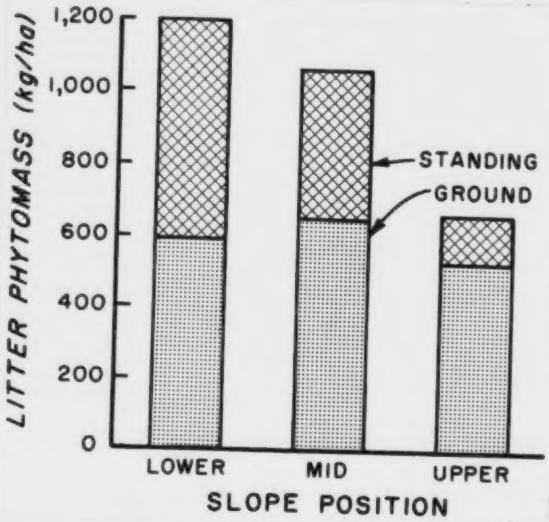

Figure 58. Average standing, ground, and total litter phytomass (kg/ha, oven-dry) on the three slope positions. $LSD_{.05}$ (standing) = 210 kg/ha; $LSD_{.05}$ (ground) = 200 kg/ha; $LSD_{.05}$ (total) = 360 kg/ha.

Soil depth generally increased from upper to lower slope positions and tall- and mid-grass species, except BOCU, were more common on deeper soils. When the same soil type occurred on different slope positions, A horizon thickness and solum depth were generally less at mid or upper slope positions than at lower slope positions.

The occurrence of certain species can be related to total available water in the solum. Tallgrass species require a greater amount of water than shortgrasses for maximum growth and would be at a disadvantage on soil types with a limited available soil water supply. Deeper soils on the watershed contained a greater available soil water storage area (Powell et al. 1978, Powell et al. 1979).

In the tallgrass prairie Bouteloua species are normally associated with areas where available soil water is a major limiting factor (Anderson and Fly 1955). In this study, Bouteloua species were more competitive on soils and under grazing conditions commonly found on upper slope positions. BOCU was less frequent on lower slopes due to its inability to compete with the tallgrasses in their normal habitat. On this watershed BOHI was more abundant than BOGR, while in western Oklahoma, BOGR would be more common than BOHI on upper slopes and shallow soils (Clements 1920).

AROL is an indicator of overgrazing, poor soil management, or other disturbances (Booth 1941, Weaver 1968). Trampling and heavy grazing by animals on upper slope locations resulted in reduced ground cover and exposed soil which may have allowed opportunistic species, such as AROL, the chance to become established. Animal behavior and preference patterns often create such areas by overgrazing and patchy grazing (Marshall 1974, Heady 1975).

Overgrazing and trampling also appeared to be the reasons for the increased occurrence of XADR on mid and upper slopes. ARLU apparently is competitive under the more favorable soil water conditions associated with deep soils and was most frequently associated with the tallgrasses. ARLU is a perennial and is normally found in the "climax" tallgrass community while XADR is an annual and not considered a part of the "climax" community as defined by USDA Soil Conservation Service range condition guides. Therefore, soil water appears to be a major factor in the occurrence of ARLU while disturbance of the soil surface by overgrazing affects the occurrence of XADR.

Most of the species mentioned are at least somewhat palatable to cattle during one or more seasons, and a plant's abundance can certainly be changed by grazing at different times of the year. Cattle selectively graze areas and plants of greater nutrient value, even when herbage is not actively growing (Baker and Powell, IN PRESS). Palatability, preference, and utilization are related, but relationships may vary due to animal factors, such as differences in individuals, stage of growth of individual, and social influences from other individuals, and plant factors, such as stage of plant development and competition among plants (Tribe 1952).

STANDING LITTER is a function of total herbage produced on a site. Therefore, if grazing pressure and herbage removal remain equal on all sites, areas with the greater herbage production will have a greater standing litter crop during the dormant season. In this study the areas with greater STANDING LITTER grazing residue were the areas with the greatest percentage of tallgrasses present. Due to cattle preference, these areas were grazed less during winter than areas dominated by Bouteloua species. Animal preference factors could lead to overutilization of a range site during any time of year if animal grazing-vegetation-site relations are not understood or considered.

Aspect--The compass bearing sectors for north-, east-, south-, and west-facing slopes were 316-45°, 46-135°, 136-225°, and 226-315°, respectively. The AOV for aspect used only the desirable tallgrass species and midgrass, shortgrass, and forb species listed in Table 20. These species accounted for about 95% of the species present in the samples. The effect of aspect on vegetation occurrence and frequency was similar for all grass species. Species frequencies were greater on north and east slopes than on south and west slopes. Because probability values for no grass or forb species class were less than 0.20, the discussion is based only on trends.

Midgrasses had the highest frequency because of the abundance of SCSC. Frequencies of all grass species were greater on northern and eastern exposures than on southern and western exposures (Figure 59). Short-, mid- and tallgrasses frequencies were similar on north and east slopes and on south and west slopes. Tall- and shortgrass frequencies were 20-25% less on west slopes than on north slopes. The decrease in tallgrasses was more evident for ANGE and PAVI than for SONU. Forb frequencies were inverse to that of short-, mid-, and tallgrass frequencies. Forbs were 11% more abundant on south and west slopes than on north slopes and 21% more abundant on the south and west slopes than on east slopes. Most differences in frequency of forbs resulted from differences in frequency of occurrence of AMPS and XADR.

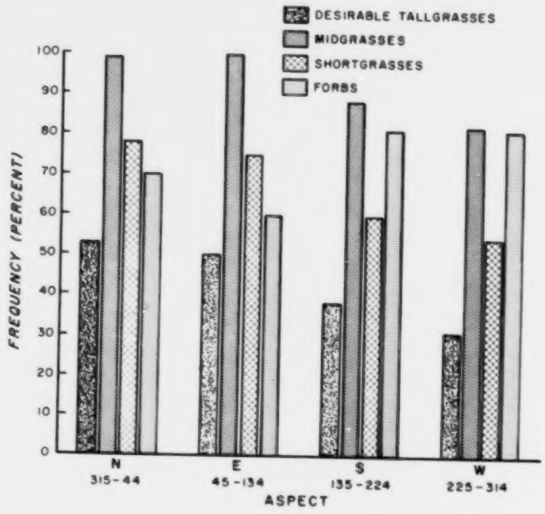

Figure 59. Frequency (%) of species classes by aspect, February 1976.

In the northern hemisphere, south slopes receive more solar insolation per unit area than north slopes. Southwest slopes are usually warmer than southeast slopes since direct sun occurs on southeast slopes shortly after periods of night cooling when dew evaporation also may delay warming (Chang 1968). Microclimatic differences cause differences in plant communities and species frequencies. Soil water losses caused by evaporation are greater on south and west slopes than on north and east slopes and create more xeric conditions. Air temperatures are often independent of aspect (Sartz 1972) but in this area evaporation on south and west slopes is increased by exposure to hot, dry southwest winds in the summer.

In the watershed study area, there were two to three times as many grass species as forb species. The trend toward lower frequencies of different grass species classes on south and west slopes indicated a lower number of grass plants, in general, and increased bare ground. Many of the forb species found on the more xeric and overgrazed slopes were relatively unpalatable and opportunistic. Annual grasses were also more common on south and west slopes, based on observation, but were not included with the perennial grasses. In general, those grass and forb species established by seed were most common in the areas with the higher percentage of bare ground.

Species changes in plant communities are common when comparing aspects within small watersheds (Zavesky 1967). During the data analysis we found that analysis of variance was not adequate for determining the desired influence of aspect. We had taken a continuous variable (aspect) and artificially divided it into classes containing a series of transects in a 90° arc, rather than transects from a midpoint aspect allowing a blending of the vegetation between aspect classes. Probability values from the AOV are similar if only N vs S, E vs W, or N, E, S, W transect differences were tested. The small scale of the watershed may also have influenced differences due to aspect so they were not as distinct as those of other regions (Smith 1977).

Soil Types--Tallgrass frequency increased as A horizon thickness increased (Table 21). All four tallgrass species were more common on the deeper Stoneburg and Zaneis soils than on the shallower Darnell and Lucien soils. Soil depth appeared to make less difference in midgrass frequency except on the Darnell where the frequency of each species, except *Carex* species, was considerably less. Shortgrass frequency was much less on the Darnell and equal on the other soils. *Paspalum* and *Bromus* spp. were the major species present on the Darnell soil type. AROL was most frequent on the Lucien and Zaneis. Forbs were least frequent on the Lucien type and nearly equal on the other soils. AMPS was most common on the Darnell and Grainola soils.

A horizon thickness and solum depth are directly correlated. Deeper soils normally have a greater water storage capacity, and unless some factor, such as texture, limits water availability, tallgrasses will be most common on deeper soils. The shallow, fine sandy loam Darnell soil supported few grass species while the Lucien, which is similar in depth and loamy-textured, supported more grass species. Darnell soils supported scattered *Quercus* spp. and *Juniperus* spp. trees which probably removed much available water from the entire solum while the Lucien supported only herbaceous species. Soil water conditions were favorable for mid- and shortgrasses on all soils except Darnell soils. The shallowness of the Lucien type and the shallow depth to the thick argillic horizon of the Grainola limited available soil water and

TABLE 21. FREQUENCY OF OCCURRENCE (%) FOR SELECTED SPECIES AND SPECIES CLASSES ON DIFFERENT SOIL TYPES

Species Class and Species	Soils					
	Darnell	Grainola	Lucien	Stoneburg	Zaneis	Prob.[1]
GRASSES						
Tallgrasses						
Desirable tallgrasses[2]	4	30	33	63	84	0.01
Andropogon gerardi	0	13	5	23	25	0.04
Panicum virgatum	4	11	14	18	34	0.50
Sorghastrum nutans	0	11	19	42	59	0.01
Andropogon virginicus	0	0	1	6	25	0.03
Midgrasses						
Schizachyrium scoparium	8	84	90	97	94	0.01
Panicum oligosanthes	17	50	60	50	69	0.13
Bouteloua curtipendula	0	60	62	37	22	0.01
Carex spp.	50	40	38	50	56	0.72
Shortgrasses						
Bouteloua hirsuta	0	25	44	31	13	0.18
Bouteloua gracilis	4	14	23	15	9	0.57
Aristida oligantha	13	54	63	38	69	0.07
Aristida spp. (perennial)	8	11	18	11	9	0.67
FORBS						
Ambrosia psilostachya	88	71	58	47	47	0.14
Artemisia ludoviciana	25	8	13	30	9	0.28
Xanthocephalum dracunculoides	17	49	19	28	9	0.12

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[1] Probability that differences in frequency of species among soil types are due to chance.

[2] Includes only *Andropogon gerardi*, *Panicum virgatum*, *Sorghastrum nutans*.

reduced tallgrass frequency. Competition for soil water between woody and herbaceous species is not often considered in Central Oklahoma rangelands. However, in this instance Darnell soils provided conditions conducive to tree growth resulting in more droughty conditions and competition for light for herbaceous plants.

Length and orientation of slopes and position on slopes correlate with the distribution (frequency) of many plant species on rangeland. Several environmental factors, such as soil water, soil type, and evaporation rate, are influenced by slope. The tallgrass prairie community is a stable community that shows the effects of differences in slope position, aspect, and soils. Most species were found to be adaptable enough to exist under the entire range of conditions. In this study tall- and midgrass species varied in frequency more with aspect on lower slope positions while frequency of short- and some midgrass species varied more on upper slope positions. All grass species classes responded similarly to increasing soil depth and north and east versus south and west aspects. The abundance of forbs was related more to soils and aspect than to slope position. Darnell soils were illustrative of soils that could support a savannah, but not the diverse herbaceous community as might be expected in the area.

Rangeland management is directly related to the grazing animal, and the grazing animal must be considered an integral part of the rangeland ecosystem. Animals, as well as plants, are influenced by slope position, soil types, and aspect. Each factor affects watering locations and resting areas, and provides for different areas for grazing as seasons change. Rangeland and management relies on knowing how to manipulate changes in the plant community by regulating grazing distribution and grazing pressure. A knowledge of plant species, soils, and physiographic sites is necessary to develop an effective grazing plan to increase animal distribution at different periods of the year to utilize more fully the production potential of the rangeland.

Grazing pressure--Differences in species frequency of occurrence due to slope position were much more evident in the moderately grazed pasture than in the lightly grazed pasture. SCSC and ANGE were more abundant on lower slopes than on upper slopes in the moderate area, but the opposite trend existed in the light area (Figure 60). Apparently these two species are adapted and competitive on upper slopes under light grazing, but not under heavier grazing. SONU, PAOL PAVI and ARLU also exhibited significant decreases in abundance as slope position increased. These decreases were not evident on the light area. Most of these species are relatively palatable during some season and decreased due to grazing pressure.

Several minor species increased in abundance with increased slope position on both the light and moderate areas (Figure 61). These included AROL, BOCU, BOHI, BOGR, *Solidago* (SOLI) spp. and XADR. Although AROL is generally considered to be an invader, it was more abundant in the light area at all slope positions than in the moderate area. BOCU was the most abundant *Bouteloua* species, but BOHI and BOGR exhibited relatively greater differences between frequencies on lower and upper slopes than did BOCU.

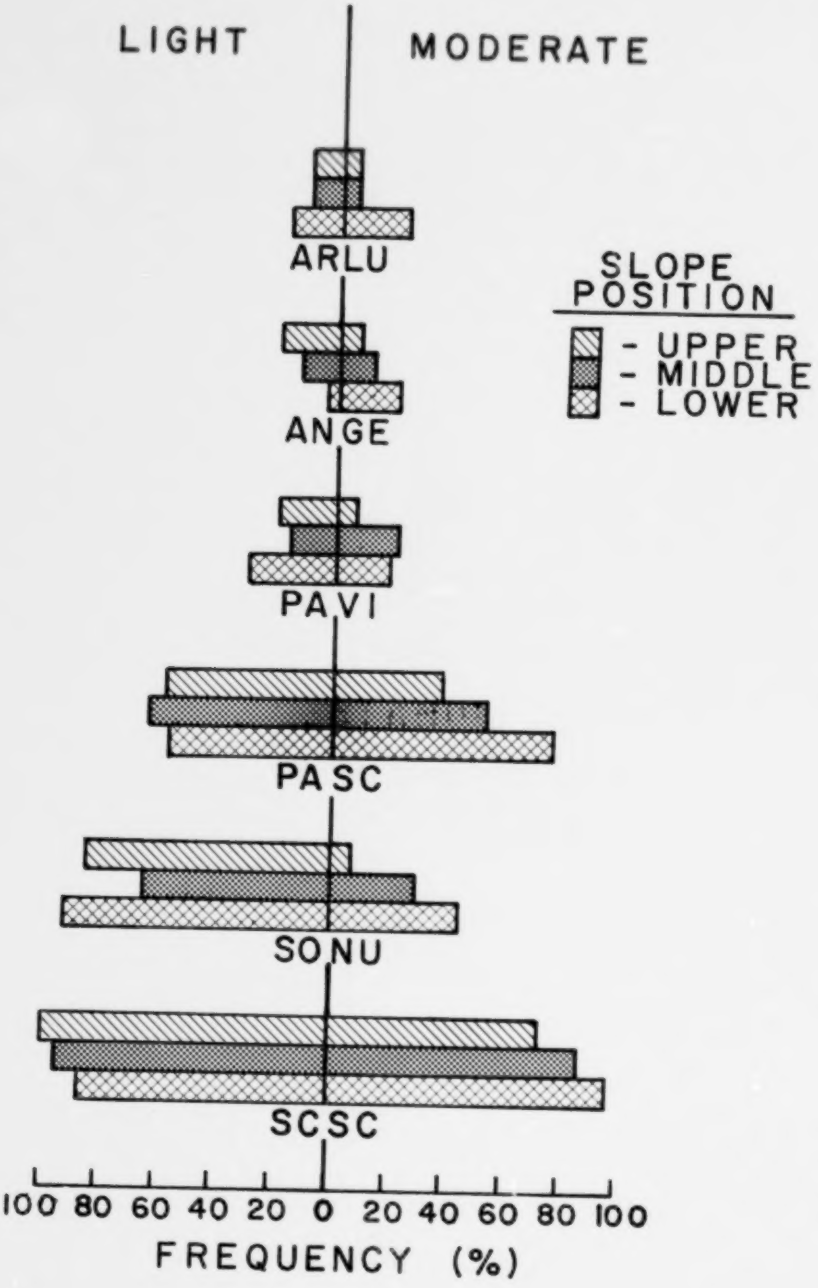

Figure 60. Frequency of dominant species in relation to slope position and grazing pressure, February 1976.

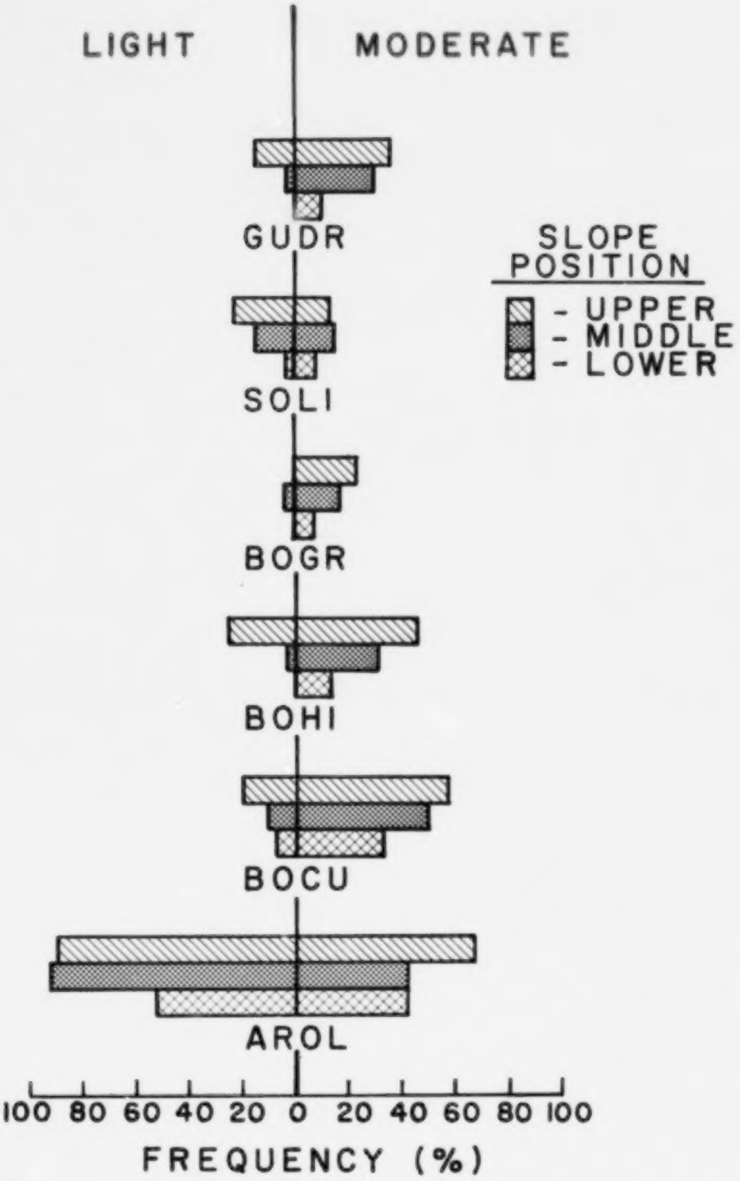

Figure 61. Frequency (%) of lower successional species in relation to slope position and grazing pressure, February 1976.

SOLI was generally more abundant on the upper slopes, but the differences were not consistent. GUDR is commonly found on disturbed soil and was much more abundant on closely grazed middle and upper slopes in the moderate area than in the light area or on lower slopes in the moderate area. Other species, such as Carex and Sporobolus spp., were relatively abundant, but showed no preference or trend concerning slope position. AMPS was equally abundant with an average of 62% frequency on all slope positions in the moderate area, but its frequency of occurrence was 80% on middle slopes and about 35% on both the upper and lower slopes in the light area. AMPS frequency was directly correlated with soil potassium content. Both soil potassium and AMPS frequencey were significantly greater on the light area, middle slopes. Soil potassium levels were highest on the upper slopes in the moderate area and the strength of correlation between AMPS frequency and soil potassium levels was also greatest on the upper slopes. Other species also demonstrated what are apparently curvilinear relationships with various soil and site factors. Additional range ecological research concerning plant species-site factor relations would be valuable for predicting species responses to range improvement practices, such as fertilization or burning.

Biomass--Biomass values for STANDING DEAD, and for GROUND LITTER on lightly grazed areas were about twice as great as on the moderately grazed area (Figure 62). The average total biomass was 2130 kg/ha on the lightly grazed area and 1000 kg/ha on the moderately grazed area. These values are very low compared to those reported in the literature for tallgrass prairie. However, several preceding years of below average precipitation and almost a complete winter grazing period prior to sampling reduced total biomass to an unusually low level.

GROUND LITTER yields were very similar on different slope positions in the moderate grazed area, but greater on the lower slopes of the lightly grazed area than on the upper and middle slopes.

Differences in STANDING DEAD due to slope position were consistent in both the light and moderate area; however, on a percentage basis, differences in STANDING DEAD was much greater on the moderate area. STANDING DEAD on the upper slopes was only 240 kg/ha, whereas the upper slope position on the light areas produced 900 kg/ha. The ratio of STANDING LITTER to GROUND LITTER was also very different on the two areas. This ratio was about 1.0 at all slope positions in the light area, but decreased from 0.97 at the lower position to 0.55 at the upper position in the moderate area. Either herbage production was very limited at the upper position in the moderate area in the 1975 growing season or else cattle were concentrating their fall and winter grazing on the ridges and upper slopes.

In general the biomass yields in samples from the light area were much more uniform that those from the moderate area. Coefficients of variation for STANDING DEAD and GROUND LITTER biomass on the light area were about half as large as those for the moderate area. The correlation between STANDING DEAD biomass and GROUND LITTER biomass was also much higher on the light area than on the moderate area. However, within the moderate area the correlation was much higher on the lower slope than on the middle or upper slope position. More spot grazing, trampling and disintegrated dung pats probably contributed to the greater variation on middle and upper slopes.

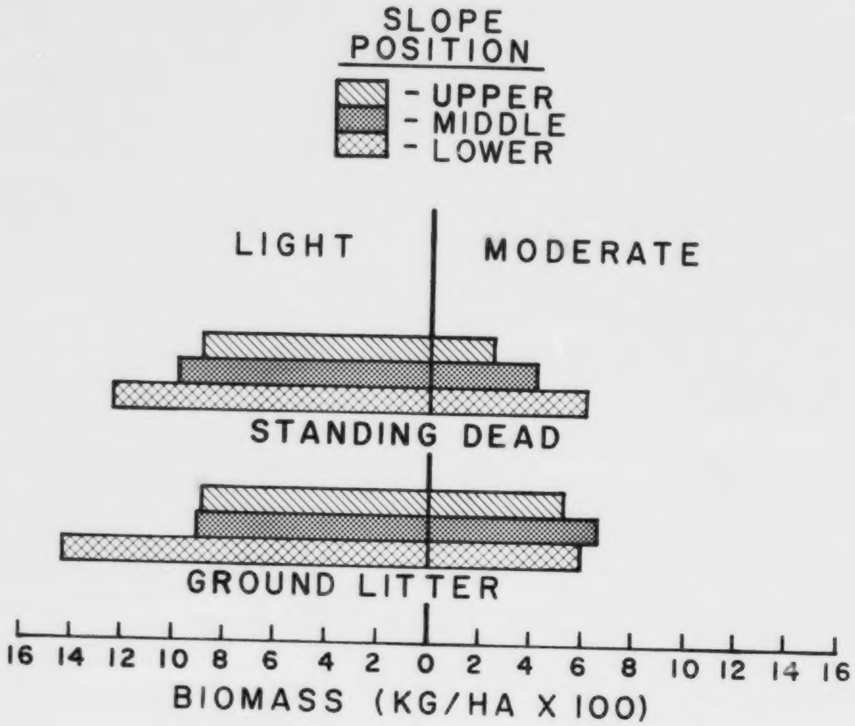

Figure 62. STANDING DEAD and GROUND LITTER biomass (kg/ha) in relation to slope position and grazing pressure, February 1976.

Part of the difference in species abundance at different slope positions or lack of difference in the light area may have been due to differences in site conditions in the two areas. This will need to be determined using replicated areas with similar conditions. A comparison of the average site factors on the two areas indicated that factors related to soil water were somewhat more favorable on the light area. These factors included aspect, slope soil depth, bulk density and organic matter. How much of a difference in these factors is necessary to cause a measurable difference in species growth and species interrelationships is not well understood.

Site Factor Regression Equations (Late Winter, 1976)

Regression equations for frequencies of six species, and STANDING DEAD and total biomass were derived using all data from the light area. Regression equations which accounted for a significant portion of the variation in each of the eight dependent variables were derived. R^2 values ranged from 60% for BOHI and STANDING DEAD to 93% for SCSC. The individual equations will not be discussed, but some generalities pertaining to all the equations can be made. STANDING DEAD and GROUND LITTER biomass values were related primarily to factors concerning effective soil water. Some of these were actual soil water content, A horizon thickness, soil depth, slope length and a Moisture Economy Index. This index was derived by multiplying percent slope by aspect. Aspect was mathematically adjusted to provide a minimum value of -1.0 for southwest-facing slopes up to a maximum of +1.0 for northeastern facing slopes. Independent variables used to predict frequencies of different species were quite variable. This was because of the wide differences in requirements and tolerances by the six species.

The derivation of a similar set of equations for the six species and two biomass variables was also attempted in the moderate area, using values from all 45 sampling area observations. This attempt was unsuccessful because site preference and grazing effects by cattle on species created differences in species frequencies that could not be predicted using only edaphic and topographic factors.

However, when the 45 observations were sorted by slope position, significant regression equations were derived for most of the eight variables at all three slope positions. STANDING DEAD biomass was the most difficult dependent variable to predict. A comparison of the total number of times an independent variable was mathematically chosen for one of the equations showed that bulk density, soil phosphorus, calcium and organic matter contents, pH, soil water and percent slope were chosen most frequently. These had the widest latitude in predicting species frequencies. Simple linear correlation analyses were used to determine species associations at the three slope positions in the moderate area. We found that slope position greatly affected the direction and degree of association between two species. Some examples of these effects included 1) SCSC was inversely related to tallgrasses, BOHI, AROL and GUDR on lower slopes, but directly related to the same species on upper slopes; 2) SCSC was directly related to AMPS, CARX and SPOR on lower slopes, but inversely related to these species on upper slopes; 3) The relationship between BOHI and BOCU was stronger as slope position increased, but the relationship between BOHI and BOGR was weaker as slope position increased; and 4) Of the relationships tested, 18 were significant on the upper slopes, but only seven were significant at the lower slopes.

Litter Chemical Composition (Late Winter, 1976)--Nitrogen, calcium and phosphorus contents in late winter STANDING DEAD and GROUND LITTER increased consistently from the lower slopes to the upper slopes on the moderate area (Figure 63). All differences due to slope position were significant at the 0.10 or less level except for phosphorus content in standing dead. The differences between phosphorus content at the lower and middle positions and that at the upper position was significant at the 0.24 level. Differences in nitrogen, phosphorus and calcium contents due to slope position in the light area were relatively small, not consistent, and none were significant at less than the 0.30 level.

All of the differences in biomass chemical contents on the moderate area were closely associated with differences in species frequencies. In general standing dead and ground litter nitrogen, phosphorus and calcium contents were low where AROL, SCSC and tallgrass species, such as ANGE, PAVI, and SONU, were abundant. These correlations were much stronger on the upper slopes than on the lower slopes. Biomass chemical contents were often directly correlated with frequencies of various forbs, such as AMPS and SOIL and various species of the *Paspalum*, *Carex* and *Sporobolus* genera. Many of these species had green leaves or winter rosettes. These were more accessible to cattle on the upper slopes and ridges where protective ground cover was less.

Plant chemical contents were also closely associated with each other whether in STANDING DEAD or in GROUND LITTER. However, the degree of association varied with the particular chemical and plant species composition in the biomass. Nitrogen and calcium were generally more closely associated with each other in either STANDING DEAD or GROUND LITTER than with phosphorus. This is the reverse of what usually occurs in live vegetation.

Plant chemical contents were closely associated with various soil chemical components, but these relationships were not consistent for all slope positions, plant components or kinds of biomass. Generally, plant chemical contents were higher on soils with a higher pH and potassium content and lower on soils with higher nitrogen and phosphorus contents. Because of the interactions of nutrient uptake and retention by different plants and the difference in species composition in our samples, we probably do not have enough samples or an adequate measure of species composition to accurately determine the relationships between dormant biomass chemical composition and soil chemical composition.

In conclusion we believe that cattle do prefer more xeric sites for late season grazing and their concentrated grazing on these sites helps to provide forage of a higher qualtiy than would be available under light grazing or on more mesic sites. To prevent excessive grazing and provide the maximum forage, a range manager could defer these areas from heavy grazing early in the summer by fencing along site boundaries where practical or by using grazing distribution practices to lead livestock away from these sites until later in the

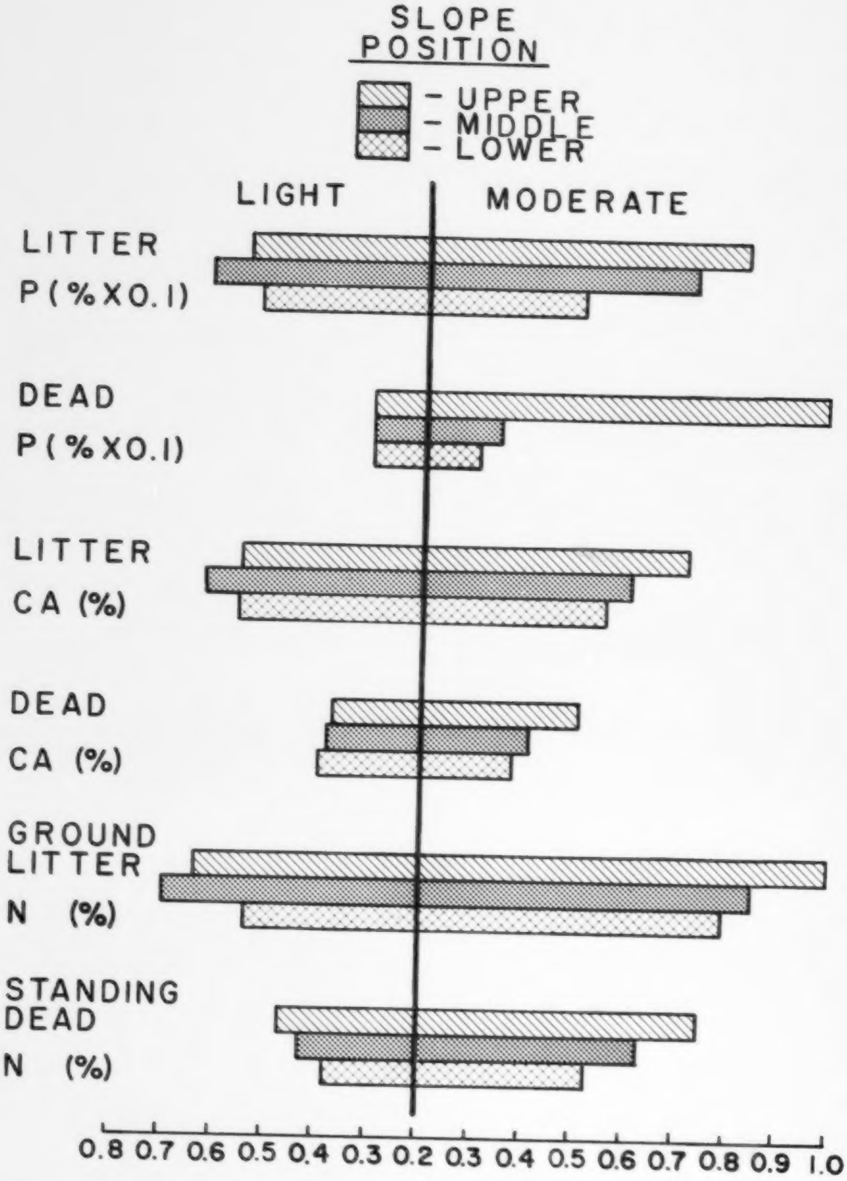

Figure 63. Chemical composition (%) of STANDING DEAD and GROUND LITTER in relation to slope position and grazing pressure, February 1976.

TYPING GUIDE SHEET

summer or fall. From the standpoint of watershed management and water quality, decreased grazing pressure along streamcourses provides a heavier cover of standing and ground litter to act as a filter for the overland flow of suspensed dung and sediment. In this regard we still need to learn how various amounts and kinds of cover affect runoff quantity and quality. Soil-plant-grazing animal interrelationships are obviously complex and will continue to produce more questions than answers. However, since successful range management depends on the wise application of ecological information, we believe research in this area and the answers that are forthcoming will be well worth the effort.

Site Factor Regression Equations (1976-78)

About 88% of the variation in total LIVE plus STANDING DEAD vegetation biomass could be accounted for using four independent site factors (Table 22). Slope position was the most influential site factor and accounted for 74% (r=+0.86) of the total variation when used alone and 46% of the variation when used in combination with the other three site factors shown in Table 22. The relationship between total STANDING vegetation and slope position was curvilinear in that STANDING vegetation was similar on upper and middle slope positions, but was much greater on lower slope positions. Because A horizon soil water content was greater on loamy prairie range sites which occurred downslope, the relationship between standing vegetation and A horizon soil water content was also curvilinear. Although the simple linear correlation coefficient between total soil water and standing vegetation was +0.64, the regression coefficient for total soil water was -4.71 when used in combination with the other three site factors in the equation. This may be a reflection of the high soil water content in soils with a high clay content in the B horizon.

LIVE vegetation was also strongly influenced by A horizon characteristics, although percent slope accounted for the greatest percentage of variation in LIVE vegetation. Slopes on the watershed ranged from only 1 to 4%, but the heaviest grazing pressure occurred on the upper, flatter slopes. Consequently, LIVE grazing residue was greater where the slopes pitched more steeply toward the drainageways.

The regression equation for STANDING DEAD was similar to that for LIVE plus STANDING DEAD. The "best" equation for STANDING DEAD indicated the negative effect of higher clay content in the B_2 horizon with a decrease of about 16 kg/ha STANDING DEAD for each additional 1% clay in the B_2 horizon.

Tallgrasses, being deep-rooted, increased with an increase in total soil water (directly related to soil depth), but decreased with increasing B_2 horizon clay content. All four of the site factors in the equation for tallgrass biomass were related to soil water with the B_2 horizon clay content probably also reflecting a negative effect on root penetration.

The percentage LIVE in the total standing vegetation was influenced most strongly, if the equation does accurately reflect cause-and-effect, by A horizon factors. The percentage LIVE was greatest on shallow prairie and other upland range sites because heavy winter and late summer grazing on upland

TABLE 22. REGRESSION EQUATIONS[1/] FOR PLANT (KG/HA) BIOMASS RESPONSE VARIABLES USING SITE FACTORS ON 25 LOCATIONS ON A TALLGRASS PRAIRIE WATERSHED GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-78

Response Variable (Y_i)	b_i	Site Factor (X_i)	Unit	% of R²	r	Range (X_i) Min.	Range (X_i) Max.
LIVE +	1032	b_o					
STANDING DEAD	19.04	(Slope position)^4 (3=low)	- -	52	+0.86	$(1)^4$	$(3)^4$
R^2 = 88.4%	9.59	(A horizon soil water)^2	%	29	+0.80	$(6)^2$	$(13)^2$
Range (1180-3860)	-4.71	Total soil water	mm	12	+0.64	17	282
Mean (2200)	2334	A horizon nitrogen	%	7	+0.17	0.001	0.188
LIVE	-57.31	b_o					
	Slope	%	55	+0.77	1	4	
R^2 = 80.9%	130	A horizon organic matter	%	19	+0.54	1.8	3.6
Range (660-1710)	33.4	A horizon soil water	%	15	+0.69	6	13
Mean (1090)	11.1	A horizon thickness	mm	11	+0.36	10	26
STANDING DEAD	662	b_o					
R^2 = 86.1%	0.54	(A horizon soil water)^3	%	38	+0.77	$(6)^3$	$(13)^3$
Range (510-2430)	8.33	(Slope position)^4	- -	35	+0.82	$(1)^4$	$(3)^4$
Mean (1110)	-15.9	B2 horizon clay	%	20	+0.04	12	58

(Continued)

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TABLE 22 (Continued)

Response Variable (Y_i)	b_i	Site Factor (X_i)	Unit	% of R^2	r	Range (X_i) Min.	Range (X_i) Max.
	1727	A horizon nitrogen	%	7	+0.12	0.001	0.188
TALLGRASSES	-259	b_o					
R^2 = 86.7	-5.81	B2 horizon clay	%	39	+0.04	12	58
Range (15-400)	1.15	Total soil water	mm	39	+0.60	17	282
Mean (150)	20.70	A horizon soil water	%	11	+0.77	6	13
	21.38	Soil water at 10-cm depth	%	11	+0.45	9	16
LIVE/(LIVE +	1276	b_o					
STANDING DEAD)(%)	-0.098	(A horizon soil water)^4	%	50	-0.43	(6)^4	(13)^4
R^2 = 72.8%	133	A horizon clay	%	25	+0.31	13	30
Range (23-64)	897	A horizon organic matter	%	17	+0.37	1.8	3.6
Mean (50)	-5390	A horizon nitrogen	%	8	-0.01	0.001	0.188

1/ Response variable differences due to location were significant at the 0.05 level. All regression coefficients are significantly different from zero at the 0.05 level.

sites removed much of the STANDING DEAD on these sites. Therefore, A horizon soil water content and nitrogen content were directly related to STANDING DEAD and inversely related to the absence of STANDING DEAD.

The relationships between site factors and certain ground cover factors are shown in Table 23. As indicated before, heavy winter grazing on flatter, shallow prairie sites reduced STANDING DEAD and increased the percentage of bare ground. Grainola soils with a higher A horizon clay content than Lucien soils (both shallow prairie range sites) received higher grazing pressure and probably greater soil compaction when soils were wet during the winter.

The A horizon soil water content was the only factor with a significant ($P < 0.05$) regression coefficient in the regression equation for surface (3-cm depth) soil temperature. This relationship is probably a reflection of A horizon soil water effect on ground cover since bare soil is warmer than soil shaded by vegetation.

LIVESTOCK GRAZING

The watershed was grazed by cow/calf pairs or only beef cows throughout the year except for a 60-day period in August and September. One bull and 15 to 20 unbred cows and and cows with calves usually grazed the watershed from May through July. Dry cows most commonly grazed the watershed in early to mid winter before calving. The watershed was grazed by an unusually large number of animals, 118 cows, only once, from 15 March to 15 April 1977.

The watershed occupies portions of two pastures. About 80% of the watershed is in one pasture and 20% in another pasture. Stocking density, grazing pressure and herbage utilization were calculated for each portion of the watershed in separate pastures and then adjusted to show average stocking density (animal units/hectare), grazing pressure (animal units/ 1000 kg of standing herbage) and utilization (kg herbage/hectare; %) for the watershed.

The stocking density on the watershed for the study period, as shown in Figure 64, ranged from a low of 0.14 a.u./ha to a high of 0.38 a.u./ha. when the watershed was grazed. The yearlong average stocking rate was 0.20 a.u./ha in 1976, 0.34 a.u./ha in 1977 and 0.28 a.u./ha in 1978. Expressed on a hectare-per-animal-unit basis, the stocking rate was 5.00, 2.94, and 3.57 ha/a.u. in 1976, 1977 and 1978, respectively.

The significance of stocking pressure in the study is related to the amount of fresh dung deposited daily during grazing and the total dung deposition for the year. Assuming an animal unit (i.e., a 450 kg. cow or equivalent based on metabolic size) ingests an average of 10.0 kg forage per day on a dry matter basis and the dry matter digestibility coefficient is 0.50, about 5.0 kg dung dry matter is deposited daily. A stocking density of 0.21 a.u./ha, as it was on the watershed from 22 January to 15 April 1976, would result in a dung deposition rate of 1.05 kg dung dry matter/ha/day. A stocking density of 0.38 a.u./ha would produce fresh dung at a rate of 1.9 kg dung dry matter/ha/day.

TABLE 23. REGRESSION EQUATIONS[1/] FOR SELECTED GROUND COVER RESPONSE VARIABLES USING SITE FACTORS ON 25 LOCATIONS ON A TALLGRASS PRAIRIE WATERSHED GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-78

Response Variable (Y_i)	b_i	Site Factor (X_i)	Unit	% of R²	r	Range (X_i) Min.	Range (X_i) Max.
BARE GROUND (%)	23.9	b_o					
R^2 = 76.2%	-0.0070	(A horizon soil water)^3	%	53	-0.75	$(6)^3$	$(13)^3$
Range (3-28)	-2.50	Slope	%	20	-0.67	1	4
Mean (13.3)	0.17	A horizon clay	%	14	-0.12	13	30
	-31.8	A horizon nitrogen	%	13	-0.27	0.001	0.188
SOIL TEMP. (C)	22.4	b_o					
R^2 = 77.3	-0.0022	(A horizon soil water)^3	%	100	-0.88	$(6)^3$	$(13)^3$
Range (17.4-22.9)							
Mean (20.2)							

[1/] Response variable differences due to location were significant at the 0.05 level. All regression coefficients are significantly different from zero at the 0.05 level.

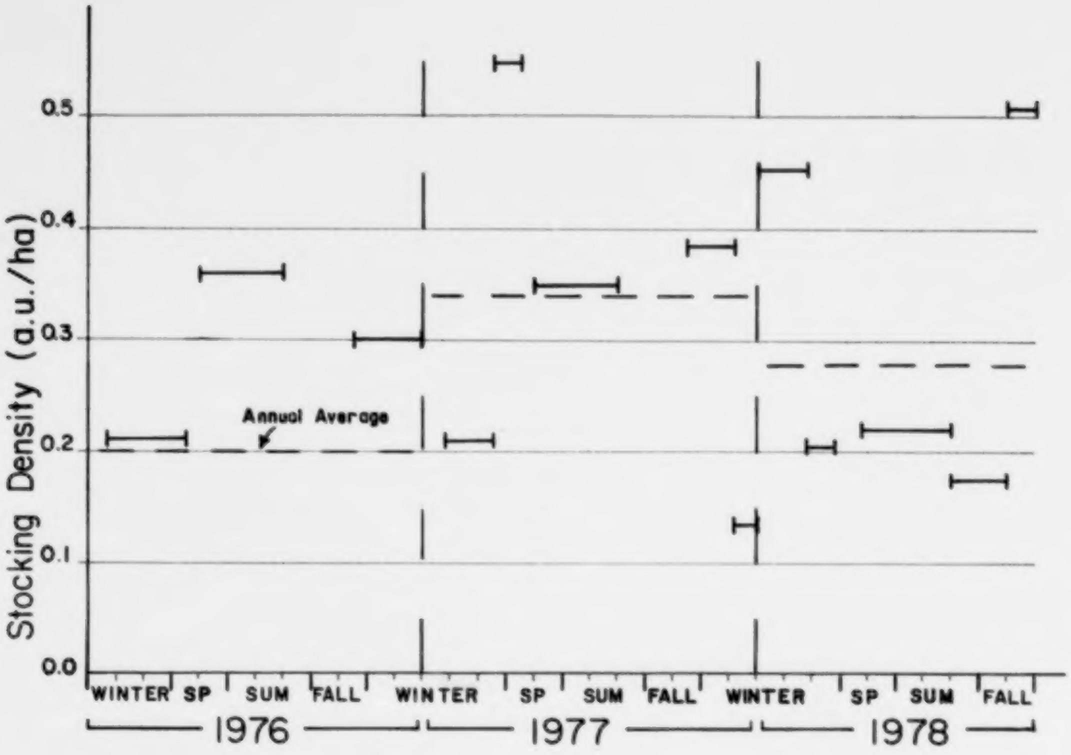

Figure 64. Stocking density (animal units/ha) during the study period.

These figures are annual averages, but can be used to approximate seasonal averages. Forage ingestion is dependent on digestibility, and digestibility is dependent on many factors. The major factors affecting digestibility include the percentage of green forage in the diet and the phenological stage of the green forage. In May and June there is adequate green forage available and it is the major part of the forage material ingested. During this season the green forage is in a vegetative stage and dry matter digestibility is 60 to 65%. The rate of ingestion at this time is about 14.0 kg dry matter/a.u./day. Consequently the dung deposition rate at a 0.35 a.u./ha stocking density is about 1.7 kg dung dry matter/ha/day . During late winter, the ingested material is all standing dead, the ingestion rate is about 8.0 kg/a.u./ day and the dry matter digestibility is 40 to 45%. With a stocking density of 0.35 a.u./ha, the dung depositon rate would also be about 1.7 kg dung dry matter/ha/day.

The major consideration concerning potential pollution is, therefore, stocking density and dung degradation rate. Because of weather conditions, biological activity and the dung chemical components, dung deposited in the spring and early summer disintegrates most rapidly and is most rapidly incorporated into the ground litter and soil. Disintegrated dung is also subject to movement by overland flow of runoff unless the movement is retarded by standing vegetation and ground litter. Therefore a more accurate measure of potential dung movement is grazing pressure or the ratio of stocking density to standing herbage. The lower the grazing pressure, the greater the ratio between herbage biomass and the dung to be held on the watershed by the herbage.

The grazing pressure (a.u./1000 kg standing herbage) for the watershed during the study is shown in Figure 65. In general grazing pressure was less variable than stocking density. However, the potentially high pollution period in late winter is shown more clearly. During this period standing herbage biomass is relatively low because of winter grazing and pressure from snow and freezing rain. If the stocking density is relatively high during this period and significant runoff occurs from late winter snow or early spring rains, there is less standing vegetation to retard dung movement into stream channels.

Additional research should be conducted to determine the exact relationship between herbage biomass, plant species composition, dung movement and factors affecting amount and season of runoff. There may be a threshold or minimum amount of standing vegetation which can be maintained to minimize dung movement. Similarly, there may be an optimum grazing pressure which produces high beef production yet maintains range sites in good condition and retains animal wastes on the watershed. Since comparable adjacent watersheds are uncommon, collecting hydrologic water quality, vegetation and grazing data on the same watershed over a long period of time may be the most practical and most accurate research approach.

UTILIZATION

Yearlong

Utilization by cattle of the live vegetation, by species classes, and of the standing dead vegetation was used to determine vegetation removed or trampled and various factors related to forage value, diet composition, selectivity and temporary changes in herbage composition due to grazing (Table 24). Determining utilization by the movable cage method requires an extremely large number of paired samples because of the inherent high degree of variability in biomass among the small, 0.5-m^2 quadrat samples. Natural variation in vegetation, site preference, and spot grazing by cattle and possible effects of cages on vegetation growth and rodent use are some of the major factors contributing to the difficulty. However, in lieu of esophageal fistulated animals for determining intake and diet composition, the movable cage method remains the most accurate and practical method of determining utilization by grazing animals on rangeland.

The values for Table 24 were determined by averaging caged and grazing residue species class biomass separately for the 175 samples (7 sampling dates X 25 samples/date). All other utilization-related factors were determined from these averages. Therefore, there is a measure of variability for biomass, but not for the derived factors.

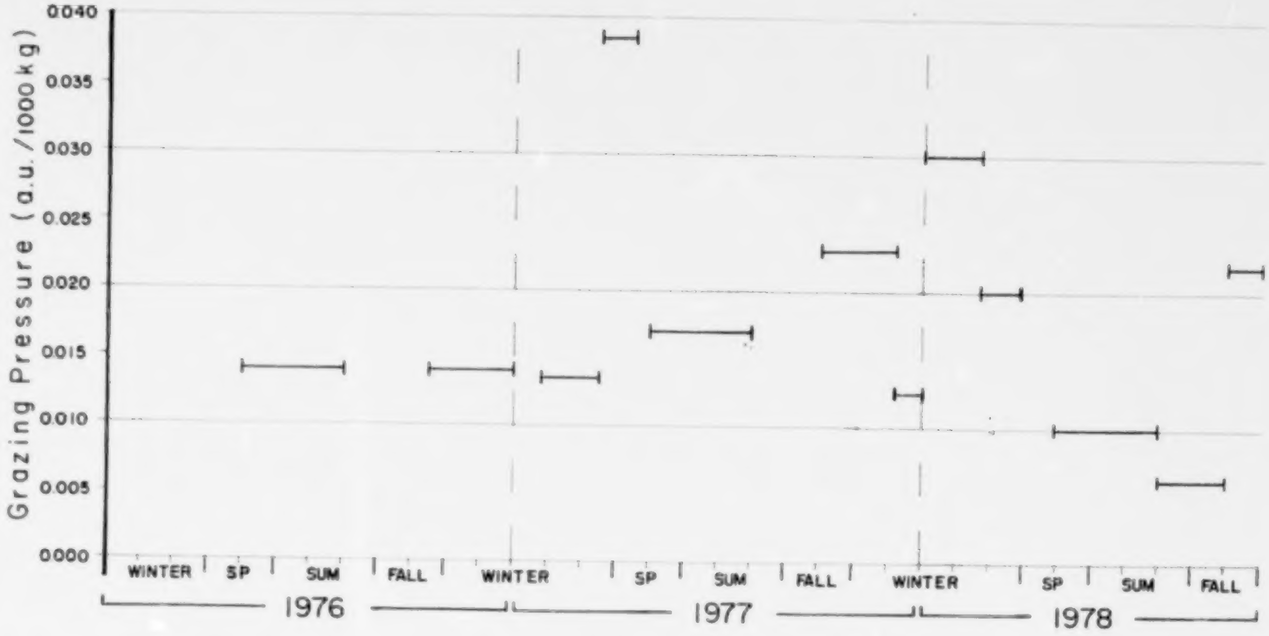

Figure 65. Grazing pressure (animal units/1000 kg herbage) during the study period.

TABLE 24. AVERAGE YEARLONG (7 UTILIZATION PERIODS[1]; 25 PAIRED SAMPLES/PERIOD) CAGED AND GRAZED HERBACEOUS SPECIES CLASS BIOMASS AND UTILIZATION FACTORS ON A TALLGRASS PAIRIE WATERSHED GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-78

Species	Caged	Grazed	Utilization		Forage Value	Diet Comp.	Selectivity	Herbage Composition %		
Class[2]	(kg/ha)	(kg/ha)	(kg/ha)[3]	(%)[4]	Index[5]	(%)[6]	Index[7]	Caged	Grazed	Diff.[8]
LIVE + DEAD	2975	2025	950	31.9						
STANDING DEAD	1645	1110	535	32.5	18.0	56.2	1.02	55.3	54.8	-0.5
TOTAL LIVE	1330	915	415	31.2	13.9	43.8	0.96	44.7	45.2	+0.5
GRASSES	890	625	270	30.0	20.1	64.3	0.96	66.9	68.0	+1.1
Tall	195	155	40	20.0	2.9	9.4	0.64	14.7	17.1	+2.4
SCSC	315	195	120	38.6	9.1	29.0	1.23	23.5	21.0	-2.5
Mid	200	165	35	18.1	2.7	8.6	0.64	14.9	17.8	+2.9
Short	65	45	20	31.3	1.5	4.8	1.02	4.7	4.7	0.0
C.S.	65	35	30	48.8	2.4	7.7	1.57	4.9	3.6	-1.3
Other	55	35	20	37.0	1.6	5.0	1.19	4.2	3.8	-0.4
FORBS	440	295	150	33.8	11.2	35.7	1.08	33.1	32.0	-1.1
Spring	60	35	25	40.7	1.8	5.5	1.28	4.3	3.8	-0.5
Early	140	95	45	33.0	3.4	11.0	1.06	10.4	10.1	-0.3
Late	245	165	80	32.6	6.0	18.9	1.03	18.3	18.0	-0.3

TABLE 24 (Continued)

1/Cage production and grazing residue sampled at end of each utilization period. Utilization periods include 12 Apr - 22 Jun 76 (71 days), 23 Jun - 17 Aug 76 (56 days), 18 Aug 76 - 29 Apr 77 (255 days), 30 Apr - 8 Jul 77 (70 days), 9 Jul 77 - 28 Mar 78 (263 days), 29 Mar - 12 Jul 78 (106 days), and 13 Jul - 9 Oct 78 (80 days). Refer to Figure 65 for grazing periods and grazing pressure.

2/Shrubs excluded because of low biomass, but very high variability. Herbaceous species classes include tallgrasses, *Schizachyrium scoparium* (SCSC), midgrasses, shortgrasses, cool season grasses, other grasses, spring forbs, early summer forbs and late summer forbs. Refer to Appendix K for listing of species in species classes.

3/Caged production - Grazed residue (e.g., Tall: 195 kg/ha - 155 kg/ha = 40 kg/ha).

4/Utilization (kg/ha)/Caged production (e.g., Tall: 40 kg/ha/195 kg/ha = 20.0%).

5/(Utilization (%) X Caged composition (%)) X 100 (e.g., Tall: 20.0% X 14.7% X 100 = 2.9).

6/Utilization (kg/ha) of a species class/Utilization (kg/ha) of all species combined. (e.g., Tall: 40 kg/ha/415 kg/ha = 9.4% tallgrasses in diet).

7/Composition of a species in diet (%)/Composition (%) of that species in total caged (available) herbage (e.g., Tall: 9.4%/14.7% = 0.64).

8/Grazed (%) - Caged (%) (e.g., Tall: 17.1% - 14.7% = +2.4%).

When utilization-related factors are determined per period, one or more species classes was determined to have a negative utilization for one or more periods. Although significant growth stimulation due to grazing is unlikely, cages in place for several months can have a negative effect on vegetation growth or provide for a more favorable habitat for rodents and insects. These may actually cause "negative utilization" by decreasing caged production. Usually, however, the negative utilization, based on only 25 paired samples, is due to chance where grazed and caged values are very similar. Since a negative utilization of one species class affects values for other species classes in succeeding computations, negative utilization creates capricious values for forage value index, diet composition, and selectivity index values.

The values presented in Table 24 are useful as long as the reader is aware of the many factors affecting grazing and utilization. Furthermore, the values presented in Table 24 for the watershed are similar to those derived using 19 growing-season and 12 dormant-season sampling dates for paired exclosure and adjacent grazed samples. Therefore, values in Table 24 can be used to describe average species class utilization for the entire 30-month study period, but not, with as much confidence, for separate periods within the 30-month study period.

The average, total LIVE and STANDING DEAD herbage utilized between 12 April 76 and 9 October 78 was 950 kg/ha or about 32% of the herbage available. This value (32%) is lower than the often-quoted maximum desirable utilization figure of 50%. The exclosure study, using 19 sampling dates during the growing season, showed that the average total LIVE vegetation in the exclosures was about 42% greater than that outside the exclosures. Even with relatively heavy winter grazing on the upper slopes, exclosures had only 50% more STANDING LITTER (31 sampling dates) than adjacent grazed areas.

The proportion of LIVE vegetation utilized (31.2%) was about the same as the proportion of standing dead utilized (32.5%). STANDING DEAD persists throughout the year and only a small amount of green vegetation is available during the dormant season. Consequently, the palatability and forage value of STANDING DEAD should be of significant concern to the rangeland grazing manager. The palatability and forage value (chemical composition and digestibility) of STANDING DEAD, as well as that of LIVE vegetation, should also be of concern to the watershed manager since 1) animal waste chemical composition is influenced by forage chemical composition (and by supplementation) and 2) dung deposition location is greatly influenced by site preference of grazing animals.

Within the LIVE vegetation, about 30% of the grass biomass and 34% of the forb biomass was utilized. These data indicate forbs, relative to grasses, are utilized to a much greater extent than commonly thought by those associated with livestock management, but not experienced in determining rangeland livestock or wildlife diets.

Several other utilization values are also somewhat contrary to "popular opinion." Utilization values for tall and midgrasses were lower than those for any forb species class and lower than those for shortgrasses, cool season grasses (primarily *Bromus japonicus*) and *Schizachyrium scoparium* (SCSC, little bluestem). Although these comparisons contradict the commonly held opinion that tallgrasses are the most preferred species, these utilization figures are the result of site selection as well as species selection. In addition, these values include utilization data from two winter grazing periods. Tallgrasses were least abundant on the sites most frequently selected for grazing by cattle. After plant maturity, tallgrasses are relatively rank (fibrous) and are not as palatable to grazing animals as are the plants of species with higher leaf:stem ratio or with smaller stems. These data indicate the importance of understanding livestock grazing behavior and site preference on rangeland watersheds with a wide variety of soils and topographic conditions. Results from small, uniform watersheds may be misleading if extrapolated to large, diverse rangeland watersheds.

Based on utilization (%) and available herbage composition (%), grasses were twice as important for forage as were forbs. Of all species classes, SCSC had the highest forage value index and was about three times more important as forage than were tallgrasses. In fact, SCSC was only slightly less important than all other grasses combined. SCSC should definitely be considered a key species on this watershed.

Grasses were estimated to contribute about 64% of the diet; forbs contributed the remaining 36%. These values, as well as all other values pertaining to species classes, are only for LIVE plants. STANDING DEAD vegetation was not differentiated as to species. Since grass plants are generally more resistant to weathering than are forbs after plant maturity, grasses no doubt contribute more than 64% of the diet during the winter period.

Forage value index figures for different species are based on availability and utilization and are therefore more independent of each other than are the values for diet composition. Diet composition values are influenced by availability and selectivity. Any selectivity index value near 1.0 indicates that species class was selected in about the same proportion as its availability. A selectivity value more than 1.0 indicates that species class was preferred and a selectivity value of less than 1.0 indicates that species class was not preferred.

In this study, SCSC, cool season grasses and spring forbs were preferred species classes, whereas tall and midgrasses were not preferred. During the fall, winter, and early spring, cool season grasses and spring forbs provide almost all of the green forage. Consequently, they are highly preferred at this time. The high selectivity index value for SCSC suggests, on a yearlong basis, SCSC is much more palatable than commonly thought. One reason SCSC is assumed to be somewhat unpalatable is its growth habit. SCSC is a bunchgrass and produces a significant number of ungrazed seed stalks. These are observed at the end of the growing season and interpreted as a sign of an unpalatable species. However, SCSC is a relatively late-maturing species, produces vegetative growth late into the summer and produces a significant number of leaves on the outer edge of the bunch. All leaf material during the vegetative phenological stage and the outer leaves after stem elongation are readily grazed by cattle.

The differences in herbage composition for caged and grazed samples were closely related to the selectivity index values. The preferred species classes had a lower percent composition in grazed samples and the less palatable species classes had a higher percent composition in grazed samples.

Grazing Period

Utilization values and differences for selected site factors within cages (ungrazed) and outside cages (grazed) for the seven utilization periods during the 30-month period are shown in Table 25. Utilization was considered the difference between the 25 caged and grazed, paired samples at the end of each utilization period including spring, summer and late summer to late winter or early spring periods. The length of the utilization periods varied from 56 days in the summer of 1976 to 263 days from mid summer, 1977 to late winter, 1978.

As expected, differences in utilization values were primarily due to differences in stocking density, the length of utilization period and the season of grazing. Therefore, interpretations concerning differences in utilization values should consider the influential conditions. The major value of the figures shown in Table 25 is in the context of how much biomass was removed by cattle during each period and the magnitude of influence of grazing on different watershed plant and soil factors during each period.

Because grazing periods varied in length, the amount utilized during a grazing period was divided by the length of that grazing period to provide a utilization-per-day figure. The total standing vegetation utilized per day varied from 0.5 kg/ha/day to 15.7 kg/ha/day. Utilization-per-day (UT/D) values were generally highest during spring and early summer and lowest during winter when forage digestibility is also lowest. The utilization figures for the 1978 late summer period were consistently low for all vegetation components. Grazing pressure was relatively low during this period, but not low enough to cause the values shown for Sampling Date 8343. Apparently, there was a difference in plant growth inside and outside the cages or significant nonlivestock utilization inside the cages. UT/D values for LIVE and for STANDING DEAD were similar in magnitude only during the first grazing period during the spring and early summer, 1976. After that period, the preference for LIVE during the growth season was obvious. Utilization of STANDING DEAD was greater during the winter when there was very little choice. These utilization figures include trampling loss as well as ingestion. Trampled STANDING DEAD is converted to herbaceous and woody GROUND LITTER, whereas about 55 to 65% of the ingested STANDING DEAD is recycled to GROUND LITTER as dung.

The UT/D values for LIVE and the different species classes of LIVE for the period ending 7180 (29 April 77) are somewhat misleading. The total LIVE utilized during this period was 690 kg/ha, but most of this utilization occurred in about 45 days instead of over the 255-day grazing period. Very little LIVE material is available before 15 March during average growing conditions. When the UT/D values were calculated during 45 days instead of 255 days, the UT/D values were 5.7 times greater. For example, UT/D for LIVE was 15.3 kg/ha/day assuming all of the difference between caged LIVE and

TABLE 25. AVERAGE GRAZING PERIOD (25 PAIRED SAMPLES/GRAZING PERIOD) BIOMASS (KG/HA, OVEN-DRY) AND SELECTED SITE FACTOR DIFFERENCES BETWEEN CAGED (UNGRAZED) AND GRAZED SAMPLING LOCATIONS ON A TALLGRASS PRAIRIE WATERSHED GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-1978

Site Factor	Sample[2/]	Sampling Date (End of Grazing Period)[1/] 6234	6290	7180	7250	8148	8254	8343	P[3/]
LIVE + DEAD	C	3750a[4/]	2960abc	3635ab	2795bc	2200c	3280ab	2230c	*
	G	2635a	2400a	1590c	1845bc	1015d	2600a	2190ab	*
	UT	1115b	560bc	2045a	950b	1185b	680bc	40c	*
	UT/D	15.7a	10.0abc	8.0abcd	13.6ab	4.5cd	6.4bcd	0.5d	*
STANDING DEAD	C	1845bc	1420cd	2540a	1035d	2165ab	1200cd	1305cd	*
	G	1275a	1255a	1100a	645b	1000ab	1075ab	1420a	*
	UT	570b	165bc	1440a	390bc	1165a	125bc	-115c	*
	UT/D	8.0a	2.9abc	5.6ab	5.5ab	4.4abc	1.2bc	-1.3c	*
LIVE	C	1905ab	1540b	1100c	1760ab	3.4d	2080a	925c	*
	G	1355ab	1145b	410d	1195b	17e	1525a	770c	*
	UT	550a	395ab	690a	565a	17c	555a	155bc	*
	UT/D	7.7a	7.1ab	2.7bcd	8.0a	0.1d	5.2abc	1.8cd	*
GRASSES	C	1230a	1100a	780b	1230a	15c	1295a	595b	*
	G	970a	830a	265c	770a	11d	970a	555b	*
	UT	260ab	270ab	515a	460a	4b	325a	40b	*
	UT/D	3.7abc	4.8ab	2.0bcd	6.6a	0.0d	3.0bcd	0.5cd	*
Tall	C	270ab	265ab	115bc	275a	1c	335a	110bc	*
	G	255a	165a	40bc	235a	1c	250a	145ab	*
	UT	15	100	75	40	0	85	-35	0.40
	UT/D	0.2ab	1.8a	0.3ab	0.6ab	0.0ab	0.8ab	-0.4b	0.35

(Continued)

TABLE 25 (Continued)

Site Factor	Sample[2]	Sampling Date (End of Grazing Period)[1] 6234	6290	7180	7250	8148	8254	8343	p[3]
SCSC	C	500a	415ab	295b	450a	0d	390ab	150c	*
	G	370a	265b	85de	200be	0e	295ab	130cd	*
	UT	130abc	150abc	210ab	250a	0c	95bc	20c	*
	UT/D	1.8abc	2.6ab	0.8bc	3.6a	0.0	0.9bc	0.2c	*
Mid	C	250ab	240ab	125c	295a	1d	305a	175bc	*
	G	200a	245a	55b	215a	3b	240a	185a	*
	UT	50	-5	70	80	-2	65	-10	0.41
	UT/D	0.7	-0.1	0.3	1.2	0.0	0.6	-0.1	0.64
Short	C	70a	90a	40ab	95a	1b	85a	60ab	*
	G	40bc	100a	15bc	70ab	1c	50abc	25bc	*
	UT	30	-10	25	25	0	35	35	0.54
	UT/D	0.4	-0.3	0.1	0.4	0.0	0.3	0.4	0.58
Cool	C	100b	20d	150a	55cd	15d	70bc	45cd	*
	G	90a	20d	50b	15c	7c	50b	10c	*
	UT	10b	0b	100a	40b	8b	20b	35b	*
	UT/D	0.2	0.0	0.4	0.6	0.0	0.2	0.4	0.16
Other	C	40bc	70ab	60b	60b	1d	105a	60b	*
	G	15bc	30b	20bc	35b	0c	85a	65a	*
	UT	25	40	40	25	1	20	-5	0.32
	UT/D	0.40	0.7	0.1	0.3	0.00	0.2	-0.1	0.30
FORBS	C	670a	440bc	315c	530b	19d	790a	330c	*
	G	390bc	315cd	145e	425b	6f	535a	210de	*
	UT	280a	125ab	170ab	105ab	13b	235a	120ab	*
	UT/D	4.0a	2.3ab	0.7b	1.5b	0.1b	2.2ab	1.3b	*

(Continued)

TABLE 25 (Continued)

Site Factor	Sample[2]	Sampling Date (End of Grazing Period)[1]							p[3]
		6234	6290	7180	7250	8148	8254	8343	
Spring	C	155a	20d	110b	40cd	5d	60c	25cd	*
	G	95a	10d	55b	25cd	3d	45bc	5d	*
	UT	60a	10c	55ab	15c	2c	15c	20bc	*
	UT/D	0.8a	0.1b	0.2b	0.2b	0.0b	0.1b	0.2b	*
Early Summer	C	235ab	130bcd	120cd	180abc	7e	275a	25de	*
	G	150b	65c	55cd	140b	2d	220a	20cd	*
	UT	85	65	65	40	5	55	5	0.68
	UT/D	1.2	1.2	0.3	0.6	0.0	0.5	0.1	0.49
Late	C	285b	295b	85c	310b	6c	455a	280b	*
	G	145c	235ab	35d	260ab	2d	290a	190bc	*
	UT	140ab	60bc	50bc	50bc	4c	165a	90abc	*
	UT/D	1.9a	1.0ab	0.2b	0.7ab	0.0b	1.6e	1.0ab	*
GROUND LITTER	C	2270ab	1820abc	1740abc	1050c	2355a	1700abc	1475bc	*
	G	2980a	2860ab	1760bcd	1040d	1540cd	1480cd	2460abc	*
	Diff.	-710b	-1040b	-20ab	10ab	815a	220ab	-985b	*
GROUND + STANDING LITTER	C	4120ab	3240bc	4280ab	2080c	4520a	2900c	2780c	*
	G	4260a	4120a	2500b	1680b	2540b	2550b	3880a	*
	Diff.	-140bc	-880bc	1780a	400b	1980a	340b	-1100c	*
LIVE + DEAD + GROUND LITTER	C	6020a	4780abc	5380ab	3840c	4550bc	5000abc	3710c	*
	G	5620a	5260ab	3050cd	2880cd	2560d	4080bc	4650ab	*
	Diff.	400bc	-480bc	2330a	960ab	1990a	920ab	-940c	*

(Continued)

TABLE 25 (Continued)

Site Factor	Sample[2]	Sampling Date (End of Grazing Period)[1] 6234	6290	7180	7250	8148	8254	8343	P[3]
LIVE %	C	56.2b	56.6b	36.7c	65.3a	2.4d	65.3a	42.3c	*
	G	55.8bc	50.0c	27.9e	64.5a	2.7f	60.2ab	37.2d	*
	Diff.	0.4	6.6	8.8	0.8	-0.3	5.1	5.1	0.13
SOIL WATER (%) (A horizon)	C	5.9b	2.6c	-	4.8bc	15.0	4.9bc	-	*
	G	5.2a	3.5d	7.3c	5.1cd	17.6a	6.3cd	12.6b	*
	Diff.	0.7	-0.9		-0.3	-2.4	-1.4		0.42
SOIL TEMP. (C)	C	24.6b	26.9a	-	25.0b	10.4c	28.5a	-	*
	G	25.2c	27.4b	19.2e	25.5bc	11.4f	29.4a	22.1d	*
	Diff.	-0.6	-0.5		-0.5	-1.0	-0.9		0.76

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[1] Sampling date (Plant year = 1 Nov. - 31 Oct.) :6---- = 1976; 6234 = 234 days after 1 Nov. 1975. Grazing periods: 6234 (120476 - 220676 = 71 days), 6290 (230676 - 170876 = 56 days), 7180 (180876 - 290477 = 255 days), 7250 (330477 - 080777 = 70 days), 8148 (090777 - 280378 = 263 days), 8254 (290378 - 120778 = 106 days), 8343 (130778 - 091078 = 89 days).

[2] C = Caged, G = Grazed, UT = Utilization, Diff = G - C, UT/D = Utilization/day.

[3] Probability level (* = P 0.05).

[4] Those values in the same row followed by the same letter are not significantly different at the 0.05 level.

grazed LIVE was caused by grazing in the last 45 days of the grazing period. UT/D values for the different species classes of LIVE can be adjusted accordingly.

GRASS UT/D values were generally highest during summer grazing periods whereas FORBS UT/D values were highest during spring grazing periods. Tallgrasses, SCSC, spring forbs and late summer forbs were the only species classes whose UT/D values were significantly ($P < .05$) different due to grazing periods. As reflected by UT/D values for GRASSES and FORBS, tallgrasses and SCSC were utilized to a greater extent during summer grazing periods and spring forbs were utilized more during the spring and early summer grazing periods. The late summer forbs UT/D value for the late summer period in 1978 was relatively higher than those of other species classes during this period. The late summer forbs UT/D value for the 1977 summer period (7250) was relatively lower than those for comparable grazing periods in 1976 (6290) and 1978 (8254). Late summer forbs production peaked earlier in 1977 than in 1976 or 1978 (Figures 53, 54 and 55, pp. 84-86). Earlier maturity in 1976 may have hastened the production of anti-quality components normally associated with late maturing, perennial forbs.

The conversion of LIVE and STANDING DEAD to GROUND LITTER is partly reflected in the low differences between caged and grazed GROUND LITTER values. The accumulation of dung and fresh GROUND LITTER on grazed areas produced GROUND LITTER values as high or higher on grazed areas as for caged samples. Differences in GROUND LITTER values for caged samples and for grazed samples due to grazing period are also influenced by the removal of all dung within all sampling areas in the spring of 1977. This is why GROUND LITTER values were lowest on the 8 July 77 sampling date.

Grazing decreased LIVE (%) during most grazing periods, but differences due to grazing period were significant at only the 0.13 level. The largest difference in LIVE (%) was in late April 77 (7180) when cattle was concentrating grazing on succulent spring forage. Soil water content (%) in the A horizon and soil temperatures were generally higher on grazed areas, but differences due to grazing periods were not significant at the 0.05 level nor were trends evident.

Effect of Site Factors

Several regression equations were developed to determine which site factors accounted for the greatest amount of variation in utilization (%) of LIVE and LIVE + DEAD (STDV) vegetation for the seven grazing periods. Regression equations shown in Table 26 may include either LIVE grazing residue or LIVE caged production, but not both in the same equation. If values were available for both grazing residue and caged production, utilization could be calculated directly without using a prediction equation.

The 25 locations were used to provide site factor values. Utilization values per location were the average utilization values for the seven sampling dates.

TABLE 26. REGRESSION EQUATIONS[1] FOR VEGETATION UTILIZATION (%) USING SITE FACTORS ON 25 LOCATIONS ON A TALLGRASS PRAIRIE GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-78

Y_i	b_i	Site Factor (X_i)	Unit	% of R^2	r	Range (X_i)	
						Min.	Max.
LIVE	25.2	b_o					
$\bar{Y}$ = 30.5%	-0.043	LIVE grazing residue	kg/ha	26	-0.54	660	1710
Range (1.7-59.4%)	-1.081	(Moisture economy index)[2]	- -	16	-0.51	$(0.33)^2$	$(5.04)^2$
R^2 = 73.3%	+1.00	Percent tallgrasses	%	16	-0.06	2.0	30.9
SE = 1.6%	+4.57	Soil water at 10-cm depth	%	15	-0.04	9.2	15.9
LIVE							
R^2 = 64.9%	23.6	b_o					
SE = 1.9%	-1.27	(Moisture economy index)^2	- -	28	-0.51	$(0.33)^2$	$(5.04)^2$
	+0.027	LIVE caged production	kg/ha	21	+0.17	810	2200
	-12.1	A horizon organic matter	%	10	-0.32	1.8	3.6
	+0.0076	A horizon calcium	ppm	6	+0.06	1560	3950
LIVE							
R^2 = 51.1%	-7.102	b_o					
SE = 2.2%	-1.374	(Moisture economy index)^2	- -	20	-0.51	$(0.33)^2$	$(5.04)^2$
	0.012	A horizon calcium	ppm	15	+0.06	1560	3950
	0.256	A horizon sodium	ppm	10	+0.44	35	123
	0.142	A horizon soil water	%	6	-0.25	6	13
DEAD	-104.0	b_o					
$\bar{Y}$ = 31.5%	0.210	A horizon potassium	ppm	36	+0.52	230	475
Range (2.9-57.0%)	0.383	A horizon sodium	ppm	17	+0.48	35	123
R^2 = 71.3%	1.56	A horizon thickness	cm	11	+0.19	10	26
SE = 2.2%	0.386	B2 horizon sand	%	7	+0.24	11	82

(Continued)

TABLE 26 (Continued)

Y_i	b_i	Site Factor (X_i)	Unit	% of R^2	r	Range (X_i) Min.	Range (X_i) Max.
LIVE + DEAD	-36.8	b_0					
$\bar{Y}$ = 30.3%	0.344	A horizon sodium	ppm	29	+0.55	35	123
Range (11.1-50.4%)	0.019	LIVE caged production	kg/ha	18	+0.37	810	2200
R^2 = 70.9%	0.088	A horizon potassium	ppm	14	+0.36	230	475
SE = 1.5%	-4.388	Slope	%	9	-0.20	1	4
LIVE + DEAD	-55.3	b_0					
R^2 = 63.0%	0.115	A horizon potassium	ppm	23	+0.36	230	475
SE = 1.7%	0.306	A horizon sodium	ppm	22	+0.55	35	123
	1.110	A horizon thickness	cm	12	+0.25	10	26
	0.242	B2 horizon sand	%	6	+0.22	11	82

1/ All equations and regression coefficients (b_i) are significant at the 0.05 level.

2/ MEI = Aspect x Slope (%).

LIVE utilization averaged 30.5% and ranged from 1.7 to 59.4% for the 25 locations sampled. About 73% of the variation in LIVE utilization could be accounted for using LIVE grazing residue, moisture economy index (MEI), percent tallgrasses in LIVE and soil water content at the 10-cm depth. LIVE grazing residue accounted for 26% of the LIVE utilization variation and the other variables collectively accounted for the other 47%. LIVE utilization was lower in areas with greater grazing residue and higher MEI values. Generally, these areas were on deeper soils on lower slope positions. The positive sign for percent tallgrasses and 10-cm depth soil water content regression coefficients is somewhat contradictory with the influence of MEI and grazing residue. Although percent tallgrasses are generally closely associated with LIVE grazing residue and MEI, cattle apparently preferred certain soils within the range of MEI and grazing residue. For example, Grainola soils have a higher A horizon soil water-holding capacity and fertility than Lucien soils and cattle were observed to graze on Grainola soils to a greater degree than on Lucien soils.

When caged LIVE production was used in a regression equation in place of LIVE grazing residue, only 65% of the variation in LIVE utilization was accounted for. LIVE utilization increased as LIVE caged production increased when the concurrent effects of MEI, A horizon organic matter content and A horizon calcium were taken into account. The positive sign for A horizon calcium content also indicates A horizon soil fertility may be a compensating factor on more xeric (lower MEI) sites.

When no plant factors were used as independent variables to predict utilization, only 51% of the variation in LIVE utilization could be accounted for. MEI accounted for 20% of the variation and A horizon factors accounted for the other 31%. A horizon calcium, sodium, and soil water contents were directly related to LIVE utilization.

Percent utilization of standing dead vegetation (DEAD) averaged 31.5% and ranged from 2.9% to 57.0%. About 71% of the variation in DEAD utilization was accounted for using A horizon potassium and sodium contents, A horizon thickness and B_2 horizon sand content. All of these independent, abiotic site factors were directly related to DEAD utilization. No regression equation using plant production or species composition values accounted for more of the variation than that accounted for using only abiotic factors. This may reflect the preference for certain sites during the winter more than a preference for production or species. DEAD utilization was not highly correlated with LIVE utilization (r=+0.33). Therefore, locations preferred for utilization of LIVE vegetation were not consistently preferred for utilization of DEAD vegetation.

The correlation coefficients between LIVE and STDV utilization and between STANDING LITTER (STDL) and STDV utilization were +0.66 and +0.88, respectively. This was as expected since STDL utilization occurred yearlong, but LIVE utilization was significant only during the growing season.

The average utilization for total standing vegetation (STDV) was 30% or about the same as for utilization of LIVE or DEAD. However, the range in STDV utilization (11-50%) over the 25 locations was much less than that

(2-59%) for LIVE utilization or that (3-57%) for DEAD utilization. About 71% of the variation in STDV utilization could also be accounted for with independent site factors. LIVE caged production was more influential than either LIVE grazing residue or total standing vegetation. The "best" four-factor regression included A horizon sodium content (29% of variation), LIVE caged production (18%), A horizon potassium content (14%) and percent slope (9%). STDV utilization decreased with increasing steepness of slope (1 to 4% slopes) and increased with increases in the other equation factors.

When only abiotic site factors were used in the regression equation, A horizon potassium and sodium contents, A horizon thickness and B_2 horizon sand content accounted for 63% of the variation in STDV utilization. This equation was very similar to the one which accounted for the greatest amount of variation in DEAD utilization.

The strong effect of minor differences in soil fertility and A horizon characteristics was also indicated by the fact that differences in LIVE, DEAD and STDV utilization between loamy prairie and shallow prairie range sites were small and not significantly different at less than the 0.60 level. Therefore, differences in utilization appear to be related to soil and topographic differences within range sites and to management factors, such as location of water, salt grounds, and feeding areas.

PLANT CHEMICAL COMPOSITION AND DIGESTIBILITY

Seasonal Variation

Seasonal variations in nitrogen, phosphorus, potassium, and calcium contents (%) for the April 76 to April 77 period are shown in Figures 66, 67, 68, and 69, respectively. Chemical components in LIVE, STANDING DEAD, GROUND LITTER, and DUNG are shown in each figure.

Nitrogen

The Kjeldahl nitrogen content in LIVE plant material declined from 2.4% in April to 1.3% in August 1976 (Figure 66). The decrease in nitrogen content with increased maturity is consistent with the findings of other researchers; however, the rapid rate of decrease was also indicative of drought and the relatively early maturity of certain species. By August, production had peaked and began to decline for all species classes except shortgrasses and late summer forbs. The increase in nitrogen content between August and September appeared to be in response to regrowth and an increased percentage of late summer forbs. Differences in dung nitrogen content in June, July, August and September were relatively large and significant, but the explanation for these differences was not apparent. Kautzsch et al. (1977) found the nitrogen content in fresh dung deposited on this watershed in July 1976 decreased only slightly from 1.9% to 1.7% in 140 days. The relatively consistent dung nitrogen content between October and March was the result of the protein and hay feeding.

GROUND LITTER was the most consistent of the materials analyzed in regard to nitrogen content. Average nitrogen content varied only 0.2%, but was

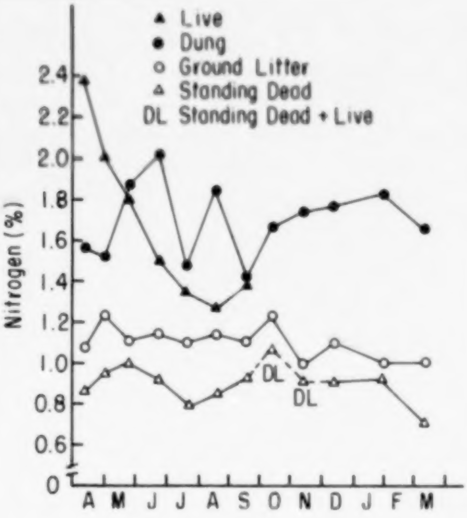

Figure 66. Average monthly Kjeldahl nitrogen content (%) of plant materials and dung during the April 1976 - March 1977 period. (Between-months probability levels or $LSD_{.05}$ were $LSD_{.05} = 0.015\%$, $P<0.19\%$, $LSD_{.05} = 0.29\%$, $P<0.17$ and $P<0.10$ for LIVE, Dung, GROUND LITTER and STANDING DEAD, respectively.)

slightly lower during winter than during summer. STANDING DEAD material was consistently lower in nitrogen content, but did indicate seasonal trends. The increase between April and late May would reflect the death of cool-season and early spring grasses and forbs. Leaching reduced the nitrogen content between May and July. With increased drought stress, leaves or entire plants of later-maturing species died and were classified as standing dead.

Phosphorus

Changes in phosphorus content in different plant materials between monthly samples were similar to change in nitrogen content in comparable plant materials (Figure 67). The lowest phosphorus levels in LIVE material and dung occurred earlier than did the lowest nitrogen levels, but the patterns were similar. Seasonal changes in dung phosphorus content were less erratic than those for dung nitrogen content. Increased concentration during digestion (Bromfield and Jones, 1970), relatively low mobility and free-choice intake of the phosphorus mineral may have caused the more consistent change in dung phosphorus content between July and late January.

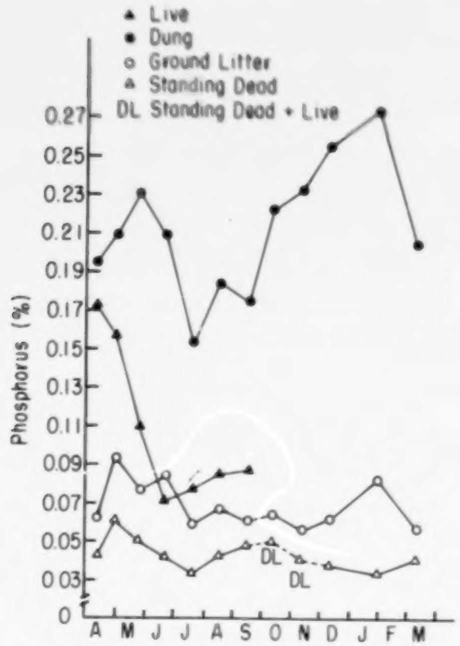

Figure 67. Average monthly phosphorus content (%) of plant materials and dung during the April 1976 - March 1977 period. (Between-months probability levels or LSD$_{.05}$ were LSD$_{.05}$ = 0.015%, $P < 0.10$, $P < 0.09$ and LSD$_{.05}$ = 0.010% for LIVE, Dung, GROUND LITTER and STANDING DEAD, respectively.)

The phosphorus content in GROUND LITTER was relatively high in spring, early summer, and January and very uniform between July and December. The seasonal pattern for phosphorus content in STANDING DEAD material was similar to that of nitrogen content in STANDING DEAD. The phosphorus content values were lower in STANDING DEAD than in other materials, had the lowest range from high to low of all materials and were the most uniform in seasonal changes.

Potassium

Although the changes in potassium content in LIVE vegetation were similar to those of nitrogen and phosphorus, the average potassium content in LIVE vegetation was much greater than that in other materials during comparable periods (Figure 68). This indicates the high degree of potassium mobility. When not active in LIVE plant material, it is easily leached from dead material (White 1973). Unlike nitrogen and phosphorus, the potassium content was generally lower in dung than in other materials except during late winter when supplements and hay were fed. The higher potassium content from June to September than in April and May indicates less leaching during the relatively dry summer months. The high values for potassium in October and November standing dead were due to the LIVE material in these samples.

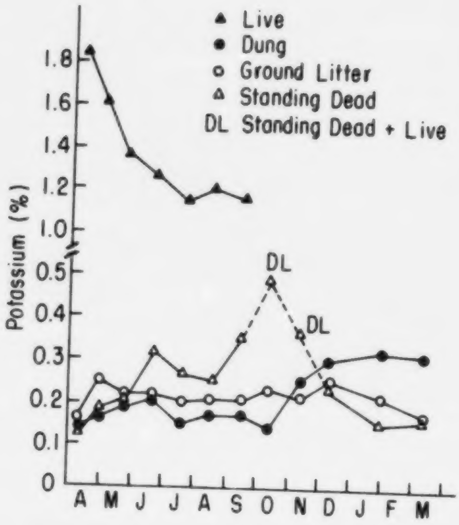

Figure 68. Average monthly potassium content (%) of plant materials and dung during the April 1976 - March 1977 period. (Between-months probability levels or $LSD_{.05}$ were $LSD_{.05}$ = 0.17%, P< 0.27, $LSD_{.05}$ = 0.25% and $LSD_{.05}$ = 0.064% for LIVE, Dung, GROUND LITTER and STANDING DEAD, respectively.)

Calcium

The values for calcium content in LIVE vegetation were more variable (P<.12) than those for other nutrients in LIVE vegetation. The pattern of seasonal change in calcium content did not coincide with the patterns for nitrogen, phosphorus, or potassium contents (Figure 69). The increase in calcium content between mid-April and early May appeared to be related to increased maturity of cool-season grasses and the increase in spring forbs, many of which were legumes. The calcium content in August coincided with peak production and a higher percentage of mid-grasses, shortgrasses, and late summer forbs. The decrease in calcium content between spring and July with a subsequent increase in August was consistent in LIVE material, GROUND LITTER and dung. As is generally conceded by many range scientists (Laycock and Price 1970) we found changes in the calcium content over time in different plant materials to be much more apparent than the explanation for these changes.

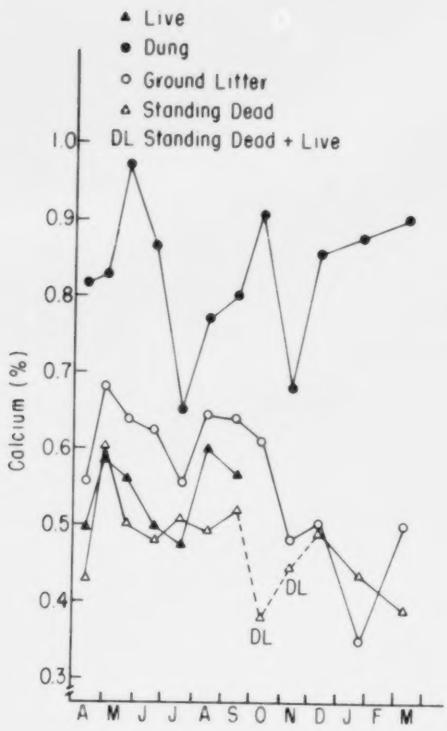

Figure 69. Average monthly calcium content (%) of plant materials and dung during the April 1976 - March 1977 period. (Between-months probability levels or $LSD_{.05}$ were $P < 12$, $LSD_{.05} = 0.17\%$, $P < 0.14$ and $LSD_{.05} = 0.08\%$ for LIVE, Dung, GROUND LITTER and STANDING DEAD, respectively.)

Compared with chemical analyses of tallgrass prairie vegetation in this area by other scientists (Briggs et al. 1948, Daniel 1935, Daniel and Harper 1935, Harper 1957, Waller et al. 1972), the average nitrogen and calcium contents in LIVE vegetation was much higher than usual, especially in summer and fall. Potassium content was about average. Phosphorus content was about average in the spring, lower during June and July and average or above average in August and September. The generally higher than reported nutrient content in our samples was because of a lower percentage of tallgrasses with corresponding higher percentage of mid and shortgrasses and forbs (Savage and Heller 1947), lower rainfall and reduced production (Daniel and Harper 1935, Harper

1957) and recycling of nutrients through grazing animals (Rouquette et al. 1973, Watkin 1957) fed supplemental feed (Benacchio et al. 1970).

Nitrogen, phosphorus, and potassium contents in LIVE vegetation decreased from a high in early spring to a low in summer at a rate that closely resembled the decrease in soil water content. Changes in STANDING DEAD composition were uniformly cyclic with seasons and generally reflected the effects of drought and plant maturity on different species classes. Changes in chemical composition of dung reflected the effects of nutrient availability in forage and supplemental feed.

Annual Variation

Vegetation for chemical analyses was not collected on the same calendar date nor at the same phenological stage during each of the three years of the study period. Therefore, trends within years are more signficant than are annual averages. Furthermore, chemical composition can be expected to vary with differences in annual growing conditions, species composition, and species utilization by grazing cattle.

Live Vegetation

As expected, nitrogen phosphorus, and potassium contents declined each year with increasing plant maturity (Table 27). For certain components, there was a slight increase in late summer as late summer forbs became more abundant or late summer rains promoted new growth. Calcium values were relatively consistent throughout the growing seasons except in 1977. The highest calcium content of that year and all three years was in vegetation collected in early September.

In 1978, nitrogen contents were generally lower throughout the growing season than in other years. Vegetation production of most species classes was highest in 1978. Much of the increased production during years of favorable growing conditions is stem material, especially in tallgrasses, and a higher stem:leaf ratio generally causes a decrease in nitrogen content of the total plant. During years of drought, forage quantity but not forage quality, is usually the factor limiting livestock production.

Ash contents were determined only in 1977 and 1978. Differences due to sampling date were highly significant in 1977, but not in 1978. However, even in 1977, ash contents varied little ranging from a low of 6.6% in early August to a high of 7.8% in early June. The relatively low ash contents resulted in the small differences between dry matter digestibility (DMD) and organic matter digestibility (OMD).

The structural carbohydrate components, acid-detergent fiber (ADF), acid-detergent lignin (ADL) and cellulose (CEL), varied greatly within years and between years. Most of this variation was attributed to changes in species composition and changes in plant maturity for different species classes. Early species, such as cool season annual grasses and forbs, matured earlier in the growing season than other species classes, but the time and rate of maturation depended greatly on temperature and soil water content each year.

TABLE 27. AVERAGE (25 SAMPLES/DAY) CHEMICAL COMPOSITION (%) OF LIVE VEGETATION ON A TALLGRASS PRAIRIE GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-78

DAY[2]	CHEMICAL COMPOSITION[1] (%)									
	N	P	K	CA	ASH	ADF	ADL	CEL	DMD	OMD
6163	2.34a[3]	0.18a	1.90a	0.50	--[4]	45.9a	11.4b	32.3a	--	--
6183	1.91b	0.16b	1.59b	0.58	--	46.6a	14.9a	22.8d	--	--
6206	1.81b	0.11c	1.37c	0.56	--	36.7c	14.9a	29.7bc	--	--
6234	1.49c	0.07d	1.28c	0.54	--	37.8bc	11.8b	31.4ab	35.4c	--
6262	1.37c	0.08d	1.17c	0.48	--	40.5b	10.1b	31.5ab	43.9b	--
6290	1.30c	0.09c	1.22c	0.62	--	39.3bc	10.2b	30.1ab	50.5a	--
6320	1.42c	0.09c	1.17c	0.58	--	36.1c	10.1b	27.8c	45.0b	--
$\bar{X}$[5]	1.66	0.11	1.38	0.55	--	40.5	12.0	29.3	42.9	--
P[6]	*	*	*	0.28	--	*	*	*	*	-- --
7192	2.27a	0.11a	1.68a	0.59ab	7.5ab	37.6b	6.9d	29.8	48.2a	49.3a
7220	1.24b	0.10a	1.37b	0.55b	7.8a	43.1a	9.2c	31.4	46.8a	49.3a
7250	1.13b	0.07b	1.13b	0.55b	6.9cd	43.7a	11.3a	31.6	49.1a	50.1a
7275	--	--	--	--	6.6d	42.2a	10.1b	30.6	47.2a	49.4a
7312	1.23b	0.09ab	1.35b	0.66a	7.2bc	42.2a	9.3c	31.6	38.8b	41.3b
$\bar{X}$	1.46	0.09	1.38	0.59	7.2	41.5	9.1	30.9	46.1	48.1
P	*	*	*	*	*	*	*	0.14	*	*

(Continued)

TABLE 27 (Continued)

DAY[2]	CHEMICAL COMPOSITION[1] (%)									
	N	P	K	CA	ASH	ADF	ADL	CEL	DMD	OMD
8176	2.16a	0.20a	2.41a	0.62	8.5	30.7c	8.0c	23.9c	58.8a	58.9a
8205	1.46b	0.11c	1.74b	0.57	7.8	37.6b	9.2abc	31.2a	49.4b	50.1b
8233	1.19c	0.09c	1.63b	0.64	8.0	40.6a	10.4a	32.4a	43.6c	45.2c
8254	1.04de	0.08c	1.55bc	0.64	7.9	39.0ab	10.0ab	31.7a	45.7bc	47.4bc
8290	1.10cd	0.09c	1.42c	0.61	7.9	39.0ab	8.5bc	30.7a	49.7b	51.3b
8317	0.93e	0.08c	1.14d	0.59	7.7	36.9b	9.0abc	28.0b	48.0b	48.7bc
8343	0.92e	0.15b	0.99d	0.54	--	--	--	--	21.7d	--
$\bar{X}$	1.26	0.11	1.55	0.60	7.9	37.7	9.3	30.0	47.0	48.7
P	*	*	*	0.76	0.64	*	*	*	*	*

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[1] N-Nitrogen, P-Phosphorus, K-Potassium, CA-Calcium, ASH-Ash, ADF-Acid-Detergent Fiber, ADL-Acid-Detergent Lignin, CEL-Cellulose, DMD-Nylon Bag Dry Matter Digestibility, OMD-Nylon Bag Organic Matter Digestibility.

[2] Plant year day: 6_ _ _ = 1976; 6163 = 163 days after 1 November 1975.

[3] Those values for the same chemical component in the same year followed by the same letter are not significantly different at the 0.05 level.

[4] Chemical analysis not conducted.

[5] Average per component per year.

[6] Probability level (* = P 0.05).

Tallgrasses, little bluestem, and late summer forbs were species classes whose plants matured latest in the growing season.

ADF, ADL, and CEL contents generally increased to a peak in mid summer, then decreased. This trend was more consistent in 1977 and 1978 than in 1976. In 1976, the usual summer onset of plant water stress occurred earlier than in 1977 and 1978. The greatest change in ADL and CEL occurred between mid April and early May, 1976 with early maturity of plants that usually mature in mid or late May. Kautzsch (1978) determined significant relationships between species composition and structural carbohydrate composition during most of the sampling periods in 1976. Ball (1980) also noted seasonal changes in structural carbohydrate composition of herbage samples from the experimental watershed in 1977 and 1978.

Dry matter digestibility (DMD) and organic matter digestibility (OMD) also varied with year and season. Changes were related to differences in plant maturity and species composition and the related differences in plant chemical composition. DMD and OMD were very closely related (r=0.98, all seasons, all years). Since ASH content was consistently and relatively low for forage, OMD was consistently, but only 1 to 2% greater, than DMD. Therefore, further discussion concerning digestibility is restricted to DMD.

Changes in DMD during the growing season each year were not as consistent as for plant chemical components. DMD was relatively low in the early summer of 1976 and 1978, increased to a peak in late summer and decreased in early fall. DMD was not determined in the early spring of 1976 or 1977, but, based on the literature and the results from 1978, DMD was no doubt highest in early spring in 1976 and 1977 also. DMD was relatively consistent for most of the growing season in 1977. A review of the species classes growth curves in Figures 53, 54, and 55 (pp. 84-86) shows a more uniform period of peak production for dominant species in 1977 than for 1976 or 1978. Apparently, those species classes whose plants undergo a rapid increase in plant water stress have a significant effect on DMD of the total herbage sample. The recent review by Hanley (1982) and the work by Hake et al. (1982), Powell (1970), Nagy and Tengerdy (1968), Nagy et al. (1969) and others indicate significant relationships between rapid decreases in soil water content, increased plant water stress, increased volative oils and other anti-quality products and DMD. However, the DMD of the herbage collected may not be representative of the DMD of the diet selected by grazing animals if there is adequate plant species diversity and grazing selection.

Standing Dead

The N, P, K, and Ca contents of STANDING DEAD vegetation (DEAD) was, as expected, less variable than that of LIVE (Table 28). The rank order of contents (%) of chemical components is presented to show the apparent effects of leaching and percent recent dead. In general, the highest values for N, P, and K were for those samples collected in early fall and very early spring. These samples included a high percentage of recent DEAD (fall) or a small percentage of green plants with high N, P, and K contents (spring). Hand separation of herbage samples is an extremely time-consuming process (i.e., about one hour per sample). In fall samples, recent (current year) DEAD is

TABLE 28. RANK ORDER BY SAMPLING DATE AND NITROGEN (N), PHOSPHORUS (P), POTASSIUM (K) AND CALCIUM (CA) CONTENTS (%) IN STANDING DEAD VEGETATION ON A TALLGRASS PRAIRIE WATERSHED GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-78

RANK	DAY	N	DAY	P	DAY	K	DAY	CA
1	7160[1/]	1.17a[2/]	7160	0.097a	8176	1.03a	7250	0.57a
2	6346	1.10ab	8017	0.077b	7347	0.72b	6183	0.56ab
3	7192	1.06abc	7347	0.072bc	7160	0.61bc	6320	0.52abc
4	6206	1.02abcd	8205	0.060bcd	7250	0.54cd	6262	0.51abcd
5	7250	0.98bcde	6346	0.060bcde	7312	0.53cd	6206	0.51abcd
6	7347	0.96bcdef	6183	0.057bcdef	8254	0.51cd	7040	0.50abcd
7	7090	0.94bcdefg	8343	0.054cdef	6346	0.51cd	7192	0.50abcde
8	6183	0.94bcdefg	6206	0.051def	8205	0.38de	6290	0.49abcde
9	6234	0.93bcdefg	8176	0.051def	7192	0.38def	8050	0.49abcde
10	6320	0.93bcdefg	7250	0.050def	7220	0.38def	7160	0.49abcde
11	7010	0.93bcdefg	8233	0.050def	6320	0.37def	7347	0.48abcde
12	7040	0.90bcdefgh	6320	0.048defg	7010	0.37def	6234	0.48abcdef
13	7312	0.87cdefghi	8148	0.047defg	8017	0.37def	8343	0.47bcdef
14	6290	0.85cdefghij	7192	0.046defg	6234	0.32efg	8254	0.46cdef
15	6163	0.84cdefghijk	6163	0.045defg	8233	0.30efgh	8290	0.45cdef
16	8205	0.83defghijk	7130	0.044defg	6262	0.27efgh	7010	0.45cdef
17	6262	0.81efghijk	6290	0.043defg	8290	0.25efgh	7090	0.45cdef
18	8176	0.78efghijk	7010	0.042defg	6290	0.25efgh	7220	0.44cdef
19	7220	0.77efghijk	8254	0.041defg	7040	0.24efgh	6163	0.44cdef
20	8148	0.77fghijk	7040	0.040defg	8148	0.23efgh	8148	0.43cdefg
21	8233	0.75ghijk	7220	0.040defg	8343	0.22efgh	8017	0.42cdefg
22	8343	0.72hijk	6234	0.039defg	8050	0.21efgh	8205	0.42defg
23	7130	0.71hijk	7312	0.039defg	6206	0.21efgh	8176	0.42defg
24	8017	0.71hijk	8290	0.038efg	6183	0.18fgh	8233	0.41defg

(Continued)

TABLE 28 (Continued)

RANK	DAY	N	DAY	P	DAY	K	DAY	CA
25	8050	0.67ijk	8050	0.038efg	7130	0.17gh	7130	0.39efg
26	8290	0.66jk	7090	0.036fg	7090	0.16gh	6346	0.38fg
27	8254	0.66jk	6262	0.035fg	6163	0.12h	8120	0.34g
28	8120	0.65k	8120	0.027g	8120	0.10h	7312	0.25h
$\bar{X}$±SE		0.85±0.05		0.049±0.006		0.36±0.05		0.45±0.03

[1] Plant year date. 6_ _ _ = 1976; 7160 = 160 days after 1 Nov 76. Winter = 001 - 135; Spring = 136 - 211; Early Summer = 212 - 242; Summer = 243 - 304; Fall = 305 - 365.

[2] Those values in the same column followed by the same letter are not significantly different at the 0.05 level.

difficult to distinguish from the DEAD of the previous year. In the early spring samples, green material is primarily very short leaves of winter rosettes of perennial plants and thin blades of cool season annual grasses. Grazing cattle also have difficulty selecting the green material from the DEAD in very early spring and consequently, prefer green material from sites where DEAD material has been removed by heavy grazing, burning, or mowing. Watershed grazing distribution can therefore be manipulated at this time by judicious use of fire, mowing, and/or fertilization.

The lowest values of N, P, and K in DEAD were in late winter and late summer. DEAD material during these periods has been subjected to a significant period of leaching. The effect of leaching is also indicated by the consistently low values of N in DEAD material collected in 1978. Rainfall in the spring and early summer of 1978 was greater than in 1976 or 1977. Phosphorus is less mobile than N and 1978 P values for DEAD material did not reflect the effect of higher rainfall leaching. Potassium (K) is very mobile and was apparently influenced more by species composition at a particular sampling date than by a difference in annual leaching by rainfall.

Except for the late winter 1978 sample, there were no significant ($P < 0.05$) differences in ASH contents due to sampling date (Table 29). The range in ASH content was only about 2% for all sampling date averages other than the value of 11.9% for STANDING DEAD collected on 28 March 1978. The reason for the relatively high ASH content in March 1978 was not apparent. The average ASH content for all 17 sampling dates was 8.4% with a standard error of 0.07%.

ADF values ranged from a low of about 45% in the fall of 1976 and 1977 to a high of 54% in early June, 1977. The overall average for ADF in STANDING DEAD was 50.7% with a standard error of 0.6%. In general, ADF values were lowest in samples containing the highest percentage of recent DEAD. No other trends were evident.

ADL values varied relatively more widely than values of ASH, ADF, and CEL. The average ADL value was 12.8% with a standard error of 0.8%. ADL values ranged from 9.0% to 17.5% with no consistent trend due to season of sample collection.

CEL values varied to about the same degree as did ADF values, but the variation with season was not as consistent as for ADF values. Values for CEL in STANDING DEAD ranged from 32.5% to 39.7% with a mean of 36.2% and a standard error of 0.8%.

DMD values varied widely (i.e., 8.7% to 42.5%) between sampling dates and within samples per sampling date. Generally, DMD values were highest when the samples contained relatively high proportions of recent DEAD or unseparated LIVE material. The lowest values were for samples collect in late winter and mid summer. Low DMD values for STANDING DEAD during the winter when there is little green forage to be selected by grazing cattle indicates most of the forage ingested is passed through the animal and deposited on the watershed as dung.

TABLE 29. RANK ORDER BY SAMPLING DATE AND ASH, ACID-DETERGENT FIBER (ADF), ACID-DETERGENT LIGNIN (ADL), CELLULOSE (CEL) CONTENTS (%) AND DRY MATTER DIGESTIBILIT (DMD, %) IN STANDING DEAD VEGETATION ON A TALLGRASS PRAIRIE WATERSHED GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-78

RANK	DAY	ASH	DAY	ADF	DAY	ADL	DAY	CEL	DAY	DMD
1	8148[1]	11.9a[2]	7220	54.2a	6206	17.5a	8050	39.7a	7347	42.5a
2	8205	9.3b	8050	53.3ab	8233	14.9b	6163	39.3a	6346	30.7b
3	7160	9.3b	7275	53.2ab	7312	14.8bc	8176	38.7ab	7160	29.6bc
4	8290	8.8b	7192	53.1ab	6320	14.0bc	6290	38.1abc	8254	26.2cd
5	7130	8.8b	6183	53.0ab	8120	14.0bcd	8205	38.0abc	7312	24.6de
6	8233	8.6b	7250	53.0ab	7275	13.9bcd	7220	37.9abcd	7275	23.5de
7	7192	8.3b	6163	52.8ab	8017	13.8bcd	6262	37.8abcd	7250	22.3ef
8	7220	8.0b	6262	52.5ab	7250	13.5bcd	6234	37.5abcd	6290	22.1efg
9	7312	8.0b	8148	52.1abc	6290	13.3bcd	7192	37.3abcde	8017	22.0efg
10	8050	7.7b	6234	52.0abc	6163	13.1bcd	6320	37.2abcde	8176	21.6efg
11	8120	7.7b	8205	51.9abc	8176	13.0bcd	6206	37.0abcde	8290	21.3efg
12	7275	7.7b	8120	51.9bcd	8254	12.9bcd	8254	36.3abcde	8233	20.4efg
13	7250	7.6b	8290	51.3bcd	7347	12.7bcd	8120	36.1abcde	7220	20.3efgh
14	8176	7.5b	6206	51.1bcd	6183	12.7bcd	7250	35.9bcde	8205	18.7fgh
15	8254	7.5b	6290	50.9bcde	8205	12.6bcd	8290	35.8bcde	6320	18.1fgh
16	8017	7.4b	8254	50.9bcde	6262	12.3cd	8148	35.6bcde	8120	17.8gh
17	7347	7.0b	8233	50.3cde	6234	12.3cd	7275	35.5bcde	7192	16.9gh
18	--	--	7312	49.8cde	8148	11.6cd	8233	35.4cde	8050	15.8h
19	--	--	8017	49.8cde	8290	11.5cd	8017	35.0cde	8148	15.0h
20	--	--	6320	49.5de	6346	11.3cd	6183	34.4de	6262	8.7i
21	--	--	8176	48.7ef	8050	10.8cde	7160	34.1e	--	--
22	--	--	7160	47.0f	7220	10.7cde	7347	33.9e	--	--
23	--	--	6346	45.3g	7192	10.1de	6346	33.7e	--	--
24	--	--	7347	45.1g	7160	9.0e	7312	32.5e	--	--
$\bar{X}$±SE		8.4±0.7		50.7±0.6		12.8±0.8		36.2±0.8		22.1±1.4

[1] Plant year date. 8___ = 1978; 8148 =148 days after 1 Nov 1977. Winter = 001-135; Spring = 136-211; Early Summer = 212-242; Summer = 243-304; Fall = 305-365.

[2] Those values in the same column followed by the same letter are not significantly different at the 0.05 level.

Chemical Interrelationships

No two chemical components in LIVE or STANDING DEAD were highly correlated (Table 30) when all samples were used in the correlation analyses. All correlation coefficients were less than 0.60. Correlations were no greater in LIVE than in DEAD. Consequently, no chemical component was judged to be a good indicator of any other component in LIVE or DEAD when samples include a high degree of variation in species composition, growing conditions, percent recent DEAD and differential effects of weathering on different chemical components.

The literature offers many examples of close correlation between many of the chemical components listed in Table 30. However, the close correlations usually occurred when the vegetation analyzed varied only in one or two factors, such as phenology in the same year, rate of fertilization or stem:leaf ratio in the same species.

More detailed analyses of these data do show that high correlations between various chemical components do exist (Kautzsch 1978, Ball 1980). As indicated, correlation coefficients were higher when analyzed were restricted to similar seasons across years or to seasons within the same year.

Although correlations were not high under the wide range of conditions, the large number of samples and wide range of conditions do support certain generalities. Those chemical components which decrease with advancing phenological stage and are leached by weathering (i.e., N, P, & K) were correlated within the range of correlation coefficients of 0.41 to 0.56. The structural carbohydrates, primarily ADF and CEL, were directly correlated with each other and inversely correlated with N, P, and K. DMD was directly related to N, P, and K and inversely related to structural carbohydrates.

Chemical Yield (Biomass X Content)

The nitrogen yield in GROUND LITTER averaged 28.4 kg/ha and ranged from 14.5 kg/ha in the spring to 42.2 kg/ha in early fall in a 12-month period (Table 31). GROUND LITTER N yield was not significantly different at the 0.05 level between early May and the mid winter collection date. The low N yield in late winter and very early spring was due primarily to the low levels of GROUND LITTER biomass at this time.

STANDING LITTER N yield averaged 10.7 kg/ha for 29 collection dates and ranged from a low of about 6.0 kg/ha to a high of 23.3 kg/ha in late fall. The relatively high values in late fall were due to the high N content in unseparated LIVE and recent DEAD at this time. In general, N is easily leached by weathering and STANDING DEAD vegetation contributed only a small portion of the total N yield.

In 1976, the LIVE N yield averaged about 15 kg/ha between mid April and mid September. LIVE N yield was highest in early summer at about the time of peak LIVE biomass. Annual averages were not suitable for comparisons because of differences in the number and dates of collection periods. However, LIVE vegetation during the growing season contributed more N yield than

TABLE 30. CORRELATION COEFFICIENTS[1] MATRIX FOR CHEMICAL COMPONENTS (%) IN LIVE (L) AND IN STANDING DEAD (D) VEGETATION ON A TALLGRASS PRAIRIE GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-78

Component		Mean	Chemical Components							
			P	K	CA	ASH	ADF	ADL	CEL	DMD
N	(L)	1.46	+0.41	+0.56	+0.14	+0.11	-0.10	+0.08	-0.32	+0.34
	(D)	0.84	+0.52	+0.47	+0.40	+0.24	-0.28	+0.17	-0.31	+0.36
P	(L)	0.11		+0.46	+0.10	+0.25	-0.03	+0.05	+0.30	+0.30
	(D)	0.05		+0.45	+0.30	+0.10	-0.31	-0.03	-0.28	+0.33
K	(L)	1.45			+0.23	+0.35	-0.20	-0.08	-0.19	+0.40
	(D)	0.36			+0.22	-0.01	-0.42	-0.03	-0.24	+0.51
CA	(L)	0.58				+0.24	-0.24	+0.01	-0.30	+0.24
	(D)	0.46				+0.07	-0.05	+0.10	-0.13	+0.15
ASH	(L)	7.6					-0.26	-0.17	-0.16	+0.21
	(D)	8.5					0.00	-0.18	-0.54	+0.01
ADF	(L)	39.8						+0.44	+0.23	-0.41
	(D)	51.0						+0.01	+0.37	-0.52
ADL	(L)	10.4							-0.23	-0.20
	(D)	13.1							+0.02	-0.03
CEL	(L)	29.9								-0.53
	(D)	36.4								-0.46
DMD	(L)	45.8								
	(D)	21.4								

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[1] Number of samples for LIVE: N, P, K and CA (450); ASH (240); ADF, ADL and CEL (385); DMD (325).
Number of samples for DEAD: N, P, K and CA (970); ASH (450); ADF, ADL and CEL (610); DMD (545).
P 0.05 if r 0.12.

TABLE 31. AVERAGE (25 SAMPLES/DAY) NITROGEN YIELD (KG/HA) IN ABOVE-GROUND VEGETATION COMPONENTS ON A TALLGRASS PRAIRIE GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-78

	Vegetation Component			
Day	Ground Litter	Standing Dead	Live	Total[1]
6163[2]	14.5c[3]	10.5efgh	7.3b	32.3cd
6183	27.4abc	10.9defgh	12.0b	51.2abc
6206	28.0abc	12.3cdef	23.2a	63.5a
6234	37.5ab	10.6egh	21.0a	69.0a
6262	33.5abc	9.7efgh	12.2b	55.4abc
6290	32.9abc	9.9efgh	14.3b	57.0ab
6320	42.2a	11.5defg	13.9	67.5a
6346	26.1abc	23.3a	--	49.3abcd
7010	27.2abc	18.6b	X̄ = 14.8 [4]	45.7abcd
7040	31.7abc	13.2cde	--	45.5abcd
7090	22.3abc	16.6bc	--	38.9bcd
7130	17.9bc[5]	8.5efgh	--	26.3d
7160	--	12.5cdef	--	--
7192	--	11.1defgh	21.5a	--
7220	--	5.6h	17.5ab	--
7250	--	6.0h	13.8b	--
7275	--	--	--	--
7312	--	7.1gh	15.06	--
7347	--	15.5bcd	--	--
8017	--	11.0defgh	X̄ = 16.9	--
8050	--	8.8efgh	--	--
8120	--	10.5efgh	--	--
8148	--	7.1gh	--	--
8176	--	6.1h	9.0c	--
8205	--	7.0gh	13.1b	--
8233	--	7.6fgh	17.7a	--
8254	--	6.8gh	16.5a	--
8290	--	7.5fgh	17.2a	--
8317	--	--	8.7c	--
8343	--	10.4efgh	8.0c	--
Mean	28.4	10.7	X̄ = 12.9	50.2

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[1] Ground Litter + Standing Dead + Live.

[2] Plant year date: 6_ _ _ = 1976; 6163 = 163 days after 1 Nov 75.

[3] Those values in the same column followed by the same letter are not significantly different at the 0.05 level.

[4] Annual mean.

[5] Chemical analysis not conducted; small, but variable amounts of Live included in Standing Dead 6346-7160 and 7347-8148.

did STANDING LITTER and less than did GROUND LITTER. Although Dung biomass was not separated from plant GROUND LITTER, it can be expected that Dung in the GROUND LITTER contributed a significant portion of the GROUND LITTER N yield.

In the 12-month period from April 1976 to March 1975, Total N yield averaged about 50 kg/ha and ranged from a low in the winter to a high in the summer. Although ground cover and protection from runoff is lowest in late winter, the watershed N load factor is also lowest at this time. Therefore, the greatest danger of nonpoint pollution in late winter and early spring on rangeland grazed by livestock is probably the direct movement of dung via overland flow. Compared to that on other kinds of land and land uses, the Total N yield on tallgrass prairie moderately grazed by cattle is relatively low. Although similar research was not conducted on this watershed, research by White (1973) indicates only a small portion of the Total N yield would be leached and transported into steamflow on a tallgrass prairie watershed.

The relationships between phosphorus (P) yield in GROUND LITTER, STANDING DEAD, LIVE and Total (Table 32) were similar to those for N yield. However, Total P yield was only about 3 kg/ha as compared to the Total N yield of 50 kg/ha. Since P content is directly correlated with N content, trends in P yield through the 12-month period were similar to those in N yield.

Compared to N and P, potassium (K) is highly mobile and easily leached from nonliving plant material. Consequently, the K yield was relatively low in GROUND LITTER and STANDING DEAD as compared to that in LIVE vegetation (Table 33). The Total K yield averaged about 16 kg/ha for the 12-month period of sampling and analyses of GROUND LITTER, STANDING DEAD, and LIVE vegetation. K yield was relatively consistent in GROUND LITTER, but highly variable in STANDING DEAD and LIVE vegetation. When the K yields in STANDING DEAD for 6346, 7347, and 8343 are compared, it can be easily seen that the unseparated LIVE in the 6346 and 7347 collection periods contributed most of the K yield in STANDING DEAD at these times.

GROUND LITTER contributed more than half of the Total calcium (CA) yield (Table 34). Although CA yield differences between collection dates were significant at the 0.05 level, trends were not apparent. CA yield in GROUND LITTER averaged about 16 kg/ha and ranged from 8.3 kg/ha to 29.1 kg/ha. Since GROUND LITTER CA content was relatively stable (Figure 69, p. 134), much of the lower CA yield in late winter was due to low GROUND LITTER biomass at this time.

STANDING DEAD CA yields were relatively consistent over time ranging from a low of 1.8 kg/ha to a high of 9.5 kg/ha. Most other low values for CA yield were about 3 to 4 kg/ha. CA content was somewhat higher in LIVE vegetation than in STANDING DEAD. Therefore, the highest values for CA yield in STANDING DEAD were in the late fall of 1976 and 1977 when STANDING DEAD samples contained unseparated LIVE vegetation. LIVE CA yields differed significantly with years, but most of the differences were due to differences in LIVE biomass.

TABLE 32. AVERAGE (25 SAMPLES/DAY) PHOSPHORUS YIELD (KG/HA) IN ABOVE-GROUND VEGETATION COMPONENTS ON A TALLGRASS PRAIRIE GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-78

	Vegetation Component			
Day	Ground Litter	Standing Dead	Live	Total[1]
6162[2]	0.92b[3]	0.57cde	0.55d	2.04c
6183	2.54ab	0.59cde	0.99b	4.21ab
6206	1.97ab	0.58cde	1.44a	3.99ab
6234	3.08a	0.44de	0.95bc	4.46a
6262	1.96ab	0.43de	0.68cd	3.07abc
6290	1.99ab	0.53cde	0.92bc	3.33abc
6320	2.69ab	0.57cde	0.85bc	4.12ab
6346	1.71ab	1.18a	--	2.89abc
7010	1.45ab	0.92ab	$\bar{X}$ = 0.91 [4]	2.37bc
7040	1.68ab	0.56cde	--	2.30bc
7090	1.93ab	0.62cd	--	2.55abc
7130	1.07b	0.43de	--	1.50c
7160	-- [5]	0.92ab	--	--
7192	--	0.35de	1.04b	--
7220	--	0.27e	1.36a	--
7250	--	0.29e	0.82b	--
7275	--	--	--	--
7312	--	0.32de	1.06b	--
7347	--	1.12a	--	--
8017	--	1.21a	$\bar{X}$ = 1.07	--
8050	--	0.47cde	--	--
8120	--	0.40de	--	--
8148	--	0.40de	--	--
8176	--	0.36de	0.86	--
8205	--	0.52cde	1.02	--
8233	--	0.54cde	1.33	--
8254	--	0.41de	1.28	--
8290	--	0.42de	1.42	--
8317	-	--	0.73	--
8343	--	0.78bc	1.37	--
Mean	1.92	0.58	($P < 0.20$) $\bar{X}$ = 1.14	3.07

[1] Ground Litter + Standing Dead + Live.

[2] Plant year date: 6_ _ _ = 1976; 6163 = 163 days after 1 Nov 75.

[3] Those values in the same column followed by the same letter are not significantly different at the 0.05 level.

[4] Annual mean.

[5] Chemical analysis not conducted; small, but variable amounts of Live included in Standing Dead 6346-7160 and 7347-8148.

TABLE 33. AVERAGE (25 SAMPLES/DAY) POTASSIUM YIELD (KG/HA) IN ABOVE-GROUND VEGETATION COMPONENTS ON A TALLGRASS PRAIRIE GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-78

	Vegetation Component			
Day	Ground Litter	Standing Dead	Live	Total[1]
6163[2]	2.3b [3]	1.4j	5.9c	9.5hij
6183	5.6ab	2.7j	10.0b	17.4def
6206	5.4ab	2.3hij	17.7a	25.4ab
6234	6.4a	3.4efghij	17.5a	27.2a
6262	5.5ab	3.1fghij	10.0b	18.6cde
6290	5.3ab	2.9fghij	13.8b	21.3bcd
6320	7.4a	4.2efghi	11.4b	23.0abc
6346	4.9ab	10.0ab	--	14.9efg
7010	5.7ab	7.3cd	X̄ = 12.3 [4]	13.0fgh
7040	7.3a	3.2fghij	--	10.6ghi
7090	4.6ab	2.6ghij	--	7.2ij
7130	4.1ab[5]	1.2j	--	5.3j
7160	--	4.9efg	--	--
7192	--	2.7ghij	15.4ab	--
7220	--	2.6ghij	19.7a	--
7250	--	3.1fghij	13.4b	--
7275	--	--	--	--
7312	--	4.4efgh	16.4ab	--
7347	--	11.2a	--	--
8017	--	5.5de	X̄ = 16.2	--
8050	--	2.6ghij	--	--
8120	--	1.4j	--	--
8148	--	1.9ij	--	--
8176	--	8.7bc	10.0c	--
8205	--	2.8fghij	15.8b	--
8233	--	3.0fghij	24.2a	--
8254	--	5.1ef	24.8a	--
8290	--	3.0fghij	22.9a	--
8317	--	--	11.2bc	--
8343	--	2.9fghij	8.9c	--
Mean	5.4	3.9	X̄ = 16.8	16.1

---

[1] Ground Litter + Standing Dead + Live.

[2] Plant year date: 6___ = 1976; 6163 = 163 days after 1 Nov 75.

[3] Those values in the same column followed by the same letter are not significantly different at the 0.05 level.

[4] Annual Mean.

[5] Chemical analysis not conducted; small, but variable amounts of Live included in Standing Dead 6346-7160 and 7347-8148.

TABLE 34. AVERAGE (25 SAMPLES/DAY) CALCIUM YIELD (KG/HA) IN ABOVE-GROUND VEGETATION COMPONENTS ON A TALLGRASS PRAIRIE GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-78

	Vegetation Component			
Day	Ground Litter	Standing Dead	Live	Total[1]
6163[2]	8.3b[3]	6.2bcdef	1.5d	16.0cd
6183	15.4ab	6.3bcdef	3.6cd	25.7bcd
6206	17.9ab	6.0cdefg	7.4a	31.2abc
6234	21.2ab	5.4defgh	7.2a	33.8ab
6262	16.9ab	6.3bcdef	4.3bc	27.6bcd
6290	20.1ab	6.0bcdefg	6.8a	30.5bcd
6320	29.1a	6.6bcde	6.2ab	42.9a
6346	13.1b	8.6ab	--	21.7bcd
7010	14.9ab	9.5a	$\bar{X}$ = 5.3 [4]	24.5bcd
7040	13.5b	7.8abcd	--	20.8bcd
7090	8.6b	8.2abc	--	16.8cd
7130	10.8b	4.5efgh	--	15.3d
7160	-- [5]	6.7bcde	--	--
7192	--	4.2efghi	5.4b	--
7220	--	3.2ghi	8.0ab	--
7250	--	3.2ghi	6.7ab	--
7275	--	--	--	--
7312	--	1.8i	9.3a	--
7347	--	8.3ab	--	--
8017	--	6.4bcdef	$\bar{X}$ = 7.3	--
8050	--	6.3bcdef	--	--
8120	--	5.4cdefgh	--	--
8148	--	4.3efghi	--	--
8176	--	3.7fghi	2.6c	--
8205	--	3.6fghi	5.1bc	--
8233	--	4.1efghi	9.6a	--
8254	--	4.6efgh	10.5a	--
8290	--	5.2defgh	10.6a	--
8317	--	--	6.1b	--
8343	--	6.7defgh	5.4bc	--
Mean	15.8	5.7	$\bar{X}$ = 7.1	25.5

---

[1] Ground Litter + Standing Dead + Live.

[2] Plant year date: 6_ _ _ = 1976; 6163 = 163 day after 1 Nov 75.

[3] Those values in the same column followed by the same letter are not significantly different at the 0.05 level.

[4] Annual Mean.

[5] Chemical analysis not conducted; small, but variable amounts of Live included in Standing Dead 6346-7160 and 7347-8148.

In summary, chemical yields were 50 kg N/ha, 25 kg CA/ha, 16 kg K/ha, and 3 kg P/ha. GROUND LITTER, usually because of its greater biomass, produced half or more of the TOTAL nutrient yields for N, P, and CA, but only 5 kg/ha of the TOTAL 16 kg K/ha. TOTAL yields were relatively low for all nutrients as compared to those from highly fertilized pastures and croplands.

Total Digestible Dry Matter (DDM) yield in standing vegetation ranged from a low of about 200 to 300 kg DDM/ha in late winter to a high of 1220 kg DDM/ha in mid summer of 1978 (Table 35). LIVE DDM yields varied relatively more than those in STANDING DEAD.

Digestibilities for N, P, K, and CA were not determined, but previous research generally indicates the digestibilities of N, P, and K are directly proportional to DMD and the N, P, and K contents. Therefore, when DMD, N, and K are high, much of the N and K yields will move through the animal and be deposited on the watershed in the urine. Most of the P ingested will be deposited as dung regardless of the DMD or P content.

Range Site Differences in Chemical Composition and Yield

Differences in LIVE plant biomass due to range sites (Table 18, p. 89) were much greater than were differences in plant chemical composition and yield (Table 36). Only K contents were significantly ($P < 0.05$) different due to range site. The average K content was slightly greater on loamy prairie range sites (1.42%) than on shallow prairie range sites (1.34%). This would indicate tallgrasses, little bluestem and/or late summer forbs (the dominant species classes on loamy prairie sites) were high in K or that the dominant plant species on shallow prairie range sites were low in K.

DMD was 3.5% higher in vegetation from shallow prairie range sites than in vegetation from loamy prairie range sites. Tallgrasses and little bluestem usually have a lower leaf:stem ratio and correspondingly lower DMD than the dominant plants on the more xeric, shallow prairie range sites.

Differences in K, ASH, and DMD yields due to range sites were influenced more by differences in plant biomass than by differences in chemical composition. Although the 0.1% difference in ASH in LIVE from loamy and shallow prairie range sites was not significant at the 0.05 level, that difference multiplied by the difference in LIVE biomass resulted in a difference of 25 kg ASH/ha ($P < 0.05$). The DMD content (%) in LIVE from shallow prairie sites was greater than that from loamy prairie range sites, but the greater LIVE biomass on loamy practice range sites resulted in 80 kg/ha more DDM yield on loamy prairie sites.

DUNG BIOMASS, DENSITY AND DEGRADATION

Based on the weight of dung collected from 30-m diameter areas around each of 25 locations on 1 April 77, dung biomass on the watershed averaged 890 kg/ha and ranged from 60 kg/ha to 2900 kg/ ha (Table 37). There was no measure of variation per location because dung was collected and weighed only once during the study. The true average dung biomass on the watershed was probably somewhat higher than 890 kg/ha because the very small particles of

TABLE 35. AVERAGE (25 SAMPLES/DAY) DIGESTIBLE DRY MATTER YIELD (KG/HA) IN STANDING VEGETATION ON A TALLGRASS PRAIRIE GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-78

	Vegetation Component		
Day	Standing Dead	Live	Total[1]
6162[2]	--[3]	--	--
6183	--	--	--
6206	--	--	--
6234	110e[4]	520b	630
6262	130e	480b	610
6290	340c	660a	1000
6320	290cd	540ab	830
6346	680b	--	680
7010	--	$\bar{X}$ = 550 [5]	--
7040	--	--	--
7090	--	--	--
7130	--	--	--
7160	320c	--	320
7192	250cde	440c	690
7220	210cde	670a	880
7250	150de	610ab	760
7275	230cde	490bc	720
7312	210cde	510bc	720
7347	790a	--	790
8017	340c	$\bar{X}$ = 550	340
8050	230cde	--	230
8120	310c	--	310
8148	220cde	--	220
8176	250cde	260e	510
8205	210cde	440d	650
8233	230cde	650bc	880
8254	270cd	740b	1010
8290	310cd	910a	1220
8317	--	580cd	--
8343	--	260e	--
Mean	300	$\bar{X}$ = 550	

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[1] Ground Litter + Standing Dead + Live.
[2] Plant year date: 6_ _ _ = 1976; 6163 = 163 days after 1 Nov 75.
[3] Chemical analysis not conducted; small, but variable amounts of Live included in Standing Dead 6346-7160 and 7347-8148.
[4] Those values in the same column followed by the same letter are not significantly different at the 0.05 level.
[5] Annual mean.

TABLE 36. LIVE PLANT CHEMICAL COMPOSITION (%) AND YIELD (KG/HA), CONTENT (%) X BIOMASS (KG/HA) ON LOAMY AND SHALLOW PRAIRIE RANGE SITES ON A TALLGRASS PRAIRIE WATERSHED GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-78

Chemical Component	Composition (%) Range Site			Yield (kg/ha) Range Site		
	Loamy	Shallow	P[1]	Loamy	Shallow	P
N	1.40	1.47	0.24	15.1	13.7	0.12
P	0.101	0.105	0.48	1.01	0.99	0.81
K	1.42	1.34	*	16.0	12.8	*
CA	0.55	0.58	0.11	6.6	6.1	0.32
ASH[2]	7.5	7.4	0.52	106.0	81.0	*
DMD	44.1	47.6	*	580.0	500.0	*
ADF	40.1	39.7	0.52			
ADL	10.4	10.3	0.85			
CEL	30.1	29.7	0.27			

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[1] Probability level ($*=P<0.05$)

[2] ASH determined only in 1977 and 1978.

TABLE 37. RANK ORDER BY LOCATION FOR DUNG BIOMASS (KG/HA, OVEN-DRY) AND DUNG PAT DENSITY (NO./HA) PRE-DUNG-REMOVAL[1] AND FOR DUNG PAT DENSITY (NO./HA) POST-DUNG REMOVAL ON A TALLGRASS PRAIRIE WATERSHED GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-78

	Biomass(kg/ha)		Density (No./ha)			
Rank	Location	Pre-Removal	Location	Pre-Removal[2]	Location	Post-Removal[3]
1	29 A[4]	2900	29 A	7360 a[5]	12 A	4010 a
2	11 B	2180	11 B	6130 b	24 B	3540 a
3	28 C	1790	28 B	5950 b	11 B	3400 a
4	12 C	1600	12 B	5870 b	27 C	2500 b
5	6 D	1390	6 C	5580 bc	5 C	2470 b
6	24 D	1310	3 D	5270 bc	6 C	2440 b
7	5 D	1270	24 D	5060 bcd	29 C	2380 b
8	3 D	1200	5 E	4770 cde	9 D	2030 bc
9	1 D	1100	9 F	4500 cdef	28 D	2020 bc
10	2 E	850	27 F	4470 cdef	23 E	1870 bcd
11	27 E	840	1 G	4140 def	4 E	1840 bcd
12	7 E	840	4 G	4060 def	3 E	1810 bcde
13	15 E	810	23 G	3900 efg	18 E	1730 bcde
14	4 E	810	7 H	3460 fgh	15 F	1250 cdef
15	9 E	730	2 H	3450 fgh	2 F	1220 cdef
16	23 E	690	15 I	2870 gh	1 G	1050 defg
17	19 E	520	19 I	2710 hi	16 G	1050 defg
18	20 E	500	10 J	2400 hij	7 G	940 efgh
19	10 F	340	20 K	1680 ijk	20 H	820 fgh
20	18 F	270	16 K	1600 jk	19 I	610 fgh
21	14 F	220	18 L	1170 kl	10 I	570 fgh
22	16 F	90	21 L	1120 kl	13 I	510 fgh
23	13 F	90	22 M	780 kl	14 J	350 fgh
24	22 F	80	13 M	670 kl	21 J	310 gh
25	21 F	60	14 N	450 l	22 K	100 h
X̄±SE	890±140		3580±390		1630±210	

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[1] All dung pats removed 1 April 77.
[2] Average of 13 sampling dates, 4/76-3/77.
[3] Average of 17 sampling dates, 4/77-10/78.
[4] Those location numbers in the same column followed by the same upper case letter were determined by SAS79 cluster analysis (Helwig and Council 1979) to be within relatively homogeneous clusters.
[5] Those means in the same column followed by the same lower case letter are not significantly different at the 0.05 level.

dung incorporated in plant ground litter were not collected. However, those particles are not considered significant in terms of additional weight nor as a source off potential pollution. Entrapment by plant ground litter should prevent movement by overland flow of runoff.

The average effective duration of dung biomass on the watershed is estimated to be about two years. The long-term stocking rate on a yearlong basis was estimated to be about 0.25 a.u./ha. During the 1976-78 study period, the yearlong average stocking rate was calculated to be 0.27 a.u./ha. The average daily dung deposition rate was calculated in the section on livestock grazing to be about 5.0 kg/day/a.u. Therefore, the annual dung deposition is estimated to be 460 kg/ha (0.25 a.u./ha X 5.0 kg/day/a.u. X 365 days/yr).

Since the average dung biomass on the watershed was estimated to be 900 kg/ha and the annual deposition rate was estimated to be 460 kg/ha, the average weight loss of dung biomass is estimated to be 50% per year. The actual weight loss rate is no doubt curvilinear as a function over time and is probably asymptotic since the weight loss would be greatest initially.

Lussenhop et al. (1982) reported that nitrogen fertilization and irrigation on an arid grassland in Colorado greatly increased the rate of dung disappearance by increasing decomposer activity. The effect of nitrogen fertilization on dung disappearance in the tallgrass prairie should also be studied as a means of speeding nutrient cycling and decreasing the dung biomass susceptible to movement by overland flow. We observed that dung pats attacked by dung beetles soon after deposition were rapidly disintegrated. However, other dung pats with no dung beetle activity soon after deposition were observed to persist intact throughout the duration of a 450-day observation period. In humid grasslands, it is fragmentation rather than decomposition that results in rapid loss of dung (Lussenhop et al. 1982).

Cluster analysis indicated about six groups of locations with similar dung biomass values (Table 37). The range within each group was about 200 to 350 kg/ha. Nine locations had higher than average dung biomass values and 16 locations had lower than average values.

The dung distribution by weight is also shown in Figure 70. The locations with the greatest dung biomass were all along the upper slopes of the watershed. Five of the six locations with the greatest dung biomass were on soils with a sandy loam surface horizon. Since cattle usually defecate after rising from their bedground, these areas may be preferred bedgrounds and resting areas. Locations 5 and 6 also serve as shading areas. Cattle may prefer sandy soils for bedgrounds in the winter since sandy soils are drier and warmer than are fine-textured soils with a higher soil water-holding capacity.

Another factor affecting dung distribution may be a slower rate of decomposition on sandy soils. Drier soils with lower soil fertility, lower soil water content and less standing vegetation and ground litter would be expected to have lower levels of metabolic activity by decomposer microorganisms.

The ranking of locations on the basis of dung pat density prior to dung removal showed a rank order similar to that for dung distribution by weight

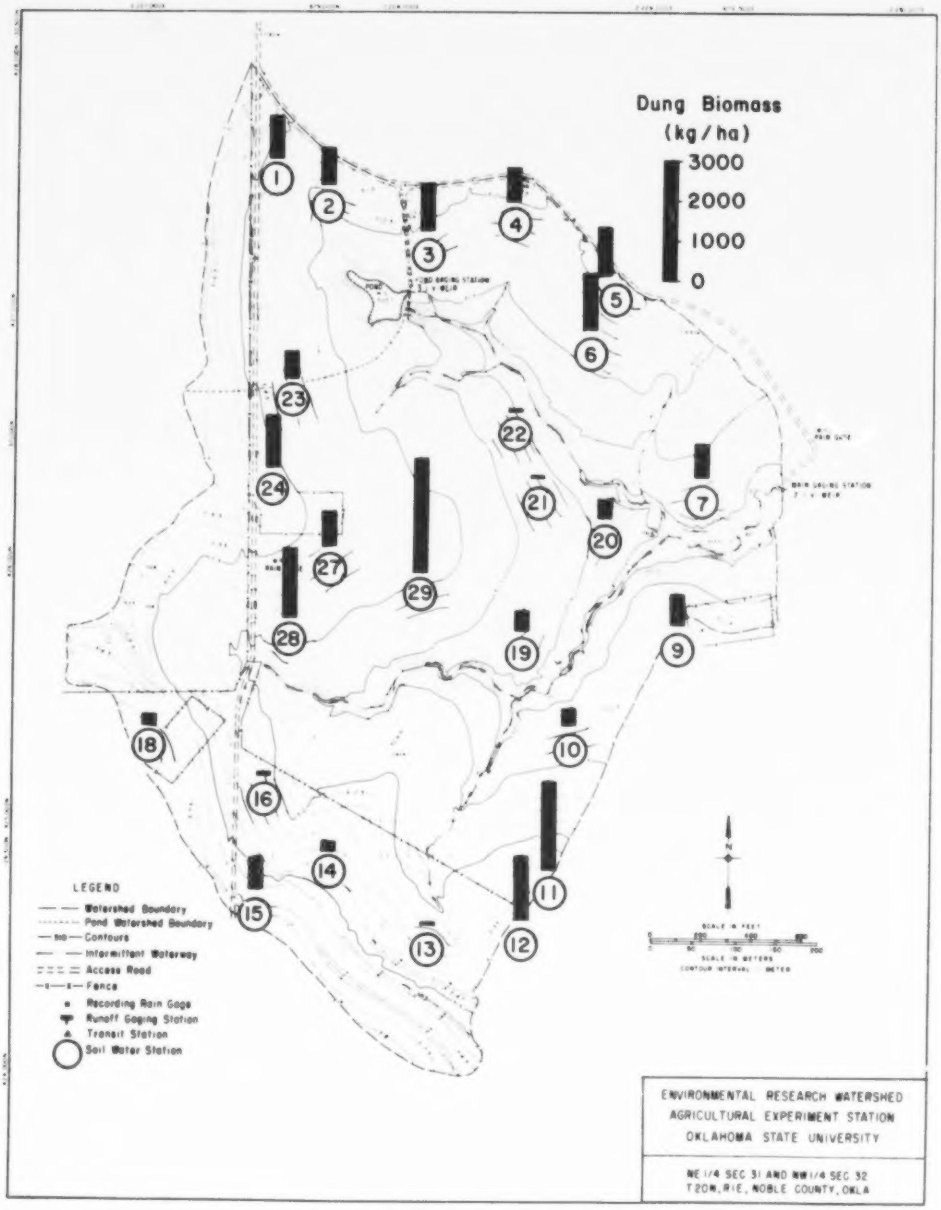
Dung Biomass
(kg/ha)
3000
2000
1000
0
1
2
3
4
5
6
7
9
10
11
12
13
14
15
16
18
19
20
21
22
23
24
27
28
29
LEGEND
Watershed Boundary
Pond Watershed Boundary
Contours
Intermittent Waterway
Access Road
Fence
Recording Rain Gage
Runoff Gaging Station
Transit Station
Soil Water Station
ENVIRONMENTAL RESEARCH WATERSHED
AGRICULTURAL EXPERIMENT STATION
OKLAHOMA STATE UNIVERSITY
NE 1/4 SEC 31 AND NW 1/4 SEC 32
T20N, R1E, NOBLE COUNTY, OKLA

Figure 70. Dung biomass (kg/ha) distribution on a tallgrass prairie watershed grazed by cattle in North Central Oklahoma.

(Table 37). The simple linear correlation coefficient between dung biomass per location and dung pat density per location was +0.93. The regression coefficient of +0.33 indicates the average dung pat weighed about 0.33 kg (SE=0.03 kg).

The correlation coefficient for dung biomass prior to dung removal and the average dung pat density per location between 1 April 77 and 9 October 78 was +0.73. Apparently, cattle changed their dung deposition habits or the dung decomposition rate had not reached a steady state for the dung with an average age of only 270 days. In addition, the period after dung removal did not include the effects of an equal number of seasons. Dung deposition distribution would be expected to vary with seasons.

The difference in accumulative dung pat density due to sampling date is shown in Figure 71. There was not a linear increase in dung pat density over time, primarily because the number of dung pats peaked in very early spring and decreased during the spring and early summer of 1978. High variation in dung pat density between locations negated between-sampling day comparisons after mid winter of 1977-78. However, predicting dung pat density over time with a quadratic equation greatly increased the percentage of variation in dung pat density that was accounted for. The R^2 value for the equation, Density = 518 + 3.8 Day, was 71% with a standard error of 105 dung pats per hectare. The R^2 value for the equation, Density = -251 + 12.0 Day - 0.0144 Day^2,

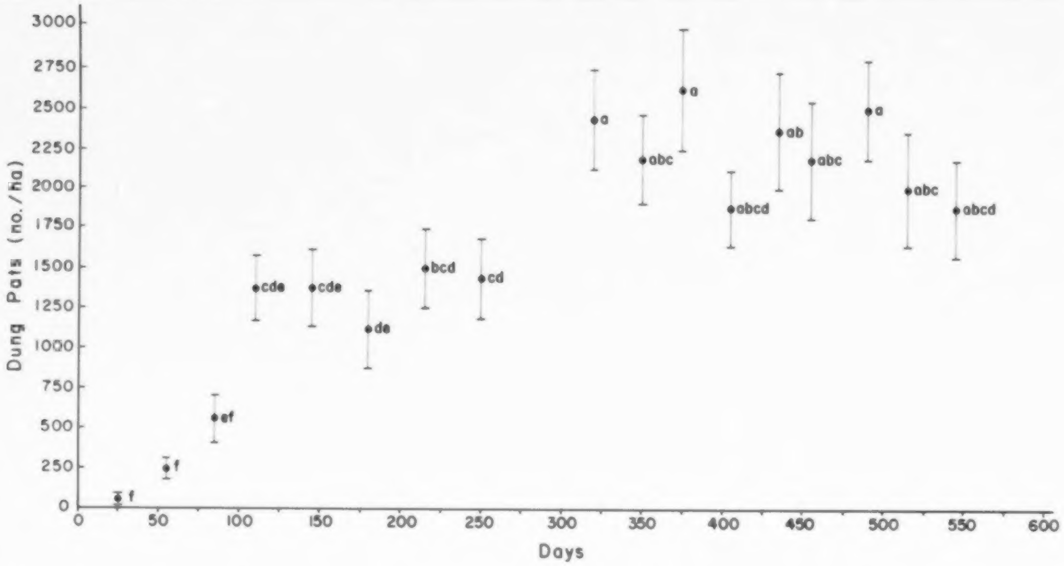

Figure 71. Accumulative dung pat density (number/ha) after 1 April 77 on a tallgrass prairie watershed grazed by cattle in North Central Oklahoma. Those values followed by the same letter are not statistically different at the 0.05 level of significance.

was 89% with a standard error of 68 dung pats per hectare. Plotting regression residuals against predicted values showed that the quadratic equation underestimated the dung pat density in the summer of 1978.

Because of the high variation between locations and the relatively short period of time after dung removal, developing an equation which best fits these limited data may lead to premature and erroneous interpretations. Therefore, it is recommended that a similar study should be conducted over a period of time which allows dung density to reach and stabilize at pre-removal levels.

Range Site Differences

Small differences in dung density and biomass due to range site (Table 38) and plots of accumulative dung density over time per location indicated similarities in dung deposition pre- and post-removal due to range site, but differences in deposition distribution patterns within range sites. As indicated in Table 38, dung deposition was much greater on shallow prairie range sites than on loamy prairie range sites. Pre-removal dung density was 2610 pats/ha on loamy sites and 5070 pats/ha on shallow sites. The ratio of pre-removal shallow prairie dung density to loamy prairie dung density was 1.94:1 indicating slightly less than twice as many dung pats on shallow sites as on loamy sites. The ratio of pre-removal shallow prairie dung biomass to loamy prairie dung biomass, however, was 2.69:1.

TABLE 38. AVERAGE DUNG PAT BIOMASS (KG/HA) AND DENSITY (NO./HA) ON LOAMY PRAIRIE AND SHALLOW PRAIRIE RANGE SITES PRE- AND POST-DUNG-REMOVAL ON A TALLGRASS PRAIRIE WATERSHED GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-78

Range Site	Sampling Period[1] Pre-removal Density	Pre-removal Biomass	Post-Removal Density
Loamy (N=12)	2610	540	1010
Shallow (N=9)	5070	1450	2480
Mean	3840	995	1745
P[2]	0.01	0.01	0.01
Ratio (Sh:L)	1.94	2.69	2.46

[1] 13 Sampling dates 4/76-3/77; all dung pats removed from sampling areas 1 April 77; 17 sampling dates 4/77-10/78.

[2] Probability level.

Dung pat size and weight may be greater on shallow prairie sites if cattle defecate greater amounts per deposition after rising from a bedground or resting area. However, another explanation is that dung decomposition is slower on more xeric, shallow prairie sites. This theory is also supported to some degree by the ratio of 2.46:1 for post-removal, shallow and loamy prairie dung densities. The post-removal dung density ratio for different sites is more like that of the pre-removal dung biomass ratio than is that of pre-removal dung density.

Predicting Dung Biomass and Density

Regression equations developed to predict pre-removal dung density and biomass and post-removal dung density accounted for about 80 to 90% of the variation (Table 39). The regression equations for pre-removal dung density and dung biomass were very similar since pre-removal dung density and dung biomass were highly correlated ($r=+0.93$). A horizon soil water and sodium contents and MEI were inversely related to dung density and biomass, whereas A horizon potassium content was directly related to dung density and biomass in both equations. In general, pre-removal dung density and biomass were greater on the warmer and more xeric sites.

A horizon potassium content was a minor, but consistent factor in all three equations predicting dung density and dung biomass. Dung density and dung biomass increased as A horizon potassium content increased.

Dung Deposition and Herbage Utilization

Dung deposition measures were not highly correlated with herbage utilization measures (Table 40). Therefore, the locations with the higher dung deposition values did not consistently have the higher herbage utilization values. The magnitude of the correlation coefficients between dung deposition and DEAD utilization were about twice the magnitude of correlation coefficients between dung deposition and LIVE utilization. Therefore, although correlation coefficients were low, cattle apparently spent more time grazing in the areas of greater dung deposition in the winter than during the growing season. As indicated in the section on herbage utilization, DEAD utilization was influenced primarily by abiotic site factors, whereas LIVE utilization was influenced to a high degree by LIVE production and species composition which were significant only during the growing season.

The relationships between dung deposition and herbage utilization may be more apparent when the LIVE and DEAD utilization values per location in Figure 72 are compared to the dung deposition values per location shown in Figure 70, p. 155. The highest dung deposition values were for those locations used as bedgrounds and resting areas and where the dung decomposition rates would be lowest. These locations coincided with the locations with a high degree of DEAD utilization, primarily on the relatively high, wide, and flat ridgetop in the west central portion of the watershed (Table 41). Both LIVE and DEAD utilization were relatively low on the lower slope positions along drainageways; however, LIVE utilization was frequently much higher than DEAD utilization in these areas. Therefore, we conclude that cattle prefer to graze green tallgrass material during the growing season, but not dead tallgrass material in any season.

TABLE 39. REGRESSION EQUATIONS[1/] FOR DUNG BIOMASS (KG/HA) AND DUNG PAT DENSITY (NO./HA) PRE-DUNG REMOVAL[2/] AND FOR DUNG PAT DENSITY (NO./HA) POST-DUNG-REMOVAL ON A TALLGRASS PRAIRIE WATERSHED GRAZED BY CATTLE IN NORTH CENTRAL OKALHOMA, 1976-78

Y_i	b_i	Site Factor (X_i)	Unit	% of R^2	r	Range (X_i) Min.	Range (X_i) Max.
Biomass	2925	b_0					
(Pre-removal)	-202	A horizon soil water	%	33	-0.74	6	13
$\bar{X}$ = 890 kg/ha	-13.3	A horizon sodium	ppm	26	-0.11	35	123
Range (60-2900)	3.02	A horizon potassium	ppm	12	+0.35	230	475
R^2 = 80.9	-1.02	(Moisture economy index)^4 3/	--	10	-0.63	(0.33)^4	(5.04)^4
SE = 67							
Density	9450	b_0					
(Pre-removal)	-613	A horizon soil water	%	46	-0.84	6	13
$\bar{Y}$ = 3580 pats/ha	-29.2	A horizon sodium	ppm	19	+0.01	35	123
Range (450-7360)	-3.03	(Moisture economy index)^4	--	13	-0.72	(0.33)^4	(5.04)^4
R^2 = 90.0%	7.83	A horizon potassium	ppm	12	+0.33	230	475
SE = 136							
Density	2300	b_0					
(Post-removal)	-878	Slope position 4/	--	61	-0.82	1	3
$\bar{Y}$ = 1630 pats/ha	-5213	A horizon nitrogen	%	9	-0.30	0.001	0.188
Range (100-4010)	4.67	A horizon potassium	ppm	8	+0.34	230	475
R^2 = 77.6%							
SE = 10.7							

[1/] All equations and regression coefficients (b_i) are significant at the 0.05 level.
[2/] All dung removed, dried and weighed 1 April 77.
[3/] MEI = Aspect X Slope (%).
[4/] 1 = Upper 1/3; 2 = Middle 1/3; 3 = Lower 1/3.

TABLE 40. CORRELATION COEFFICIENTS MATRIX FOR DUNG DEPOSITION AND HERBAGE UTILIZATION MEASURES FROM 25 LOCATIONS ON A TALLGRASS PRAIRIE WATERSHED GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-78

	DUNG[1]		UTILIZATION[2]		
	Post-Removal Density	Pre-Removal Biomass	LIVE	DEAD	STDV
DUNG (Pre: density)	0.81	0.93	0.16	0.33	0.14
DUNG (Post: density)		0.73	0.13	0.35	0.13
DUNG (Pre: biomass)			0.09	0.24	0.06
UTILIZATION (LIVE)				0.33	0.66
UTILIZATION (DEAD)					0.88

[1] DUNG: Pre-removal density (pats/ha), Post-removal density (pats/ha), Pre-removal biomass (kg/ha).

[2] UTILIZATION: LIVE (%), DEAD (Standing Dead, %), STDV (Total Standing Vegetation, %).

In summary, the most important consideration from a dung deposition and potential pollution standpoint is not where on a watershed cattle graze, but where they choose for bedgrounds and resting areas. The danger of dung movement into steamflow appears to the greatest in the spring when aboveground vegetation biomass is lowest and the dung load factor and probability of runoff are highest. Therefore, livestock grazing distribution and watershed management practices designed to minimize potential pollution should consider livestock behavior. Where possible, maximum standing and ground cover should be maintained on areas receiving the greatest dung deposition. Dung decomposition should be increased to minimize the steady-state dung biomass. Personal observations indicate birds often help speed fragmentation when undigested grain, such as whole milo, passes through cattle and is available in the dung. Dung pats attacked by birds are rapidly fragmented and incorporated into ground litter before the impervious crust hardens.

Chemical Composition Changes Over Time

Changes in nitrogen, phosphorus, potassium, and calcium contents of dung in place on the watershed for various periods of time were not consistent with respect to nutrient or season of deposition (Table 42). The N contents of dung deposited in July 1976 were more inconsistent than those deposited at other times. The N contents in dung deposited in September 1977 changed very little, whereas N contents in dung deposited in January and May 1978 decreased over time. Averaged over all deposition seasons, there was only a

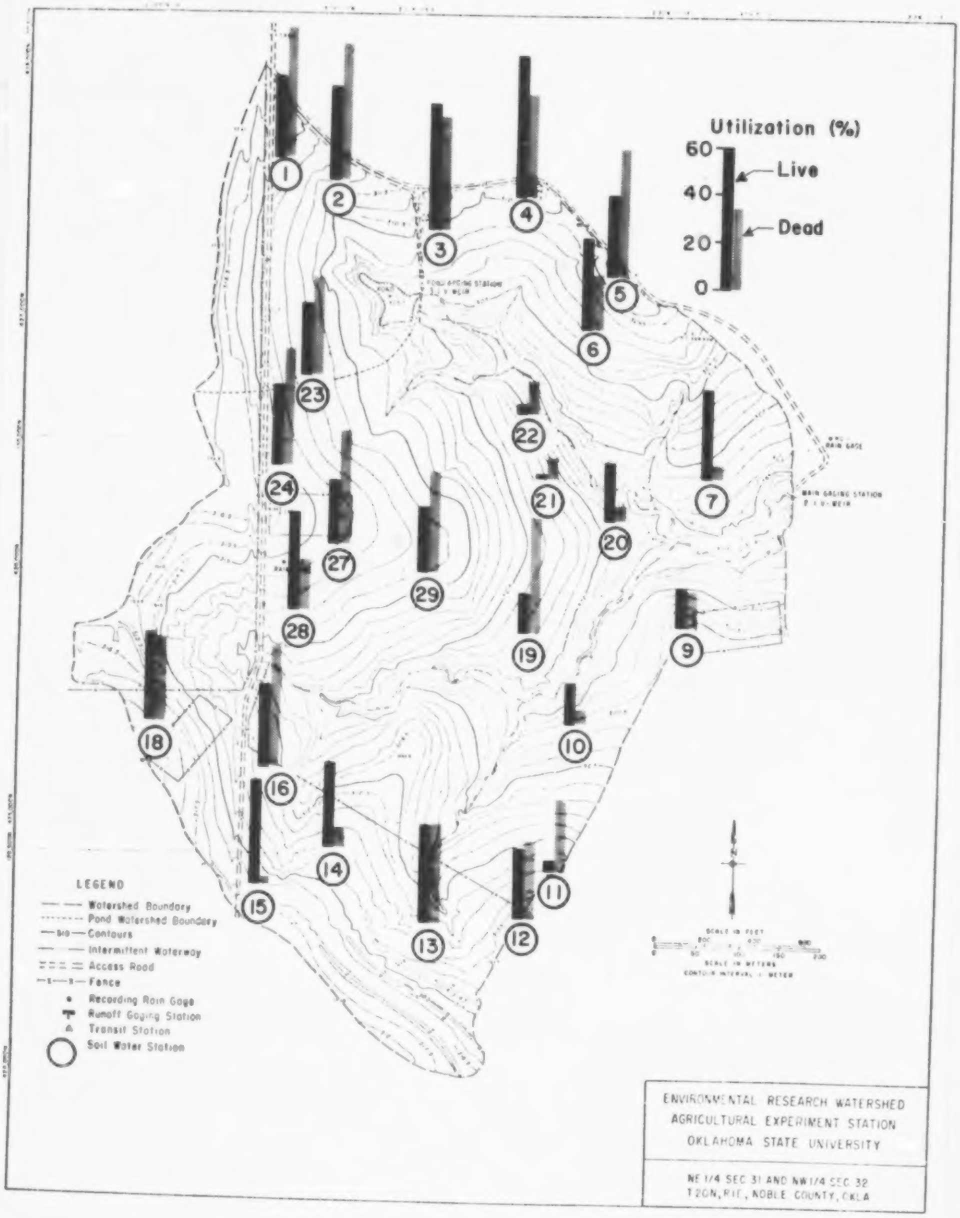
Utilization (%)
60
40
20
0
Live
Dead
1
2
3
4
5
6
7
9
10
11
12
13
14
15
16
18
19
20
21
22
23
24
27
28
29
MAIN GAGING STATION
LEGEND
Watershed Boundary
Pond Watershed Boundary
Contours
Intermittent Waterway
Access Road
Fence
Recording Rain Gage
Runoff Gaging Station
Transit Station
Soil Water Station
SCALE IN FEET
SCALE IN METERS
CONTOUR INTERVAL 1 METER
ENVIRONMENTAL RESEARCH WATERSHED
AGRICULTURAL EXPERIMENT STATION
OKLAHOMA STATE UNIVERSITY
NE 1/4 SEC 31 AND NW1/4 SEC 32
T20N, R1E, NOBLE COUNTY, OKLA

Figure 72. Average (7 grazing periods) utilization (%) of LIVE and STANDING DEAD herbage by sampling location on a tallgrass prairie watershed grazed by cattle in North Central Oklahoma, 1976-78.

TABLE 41. RANK ORDER BY LOCATION FOR AVERAGE (7 GRAZING PERIODS) UTILIZATION (%) OF VEGETATION COMPONENTS ON A TALLGRASS PRAIRIE WATERSHED GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-78

Rank	Location	LIVE	Location	DEAD[1]	Location	L+D[2]
1	4 A[3]	59.4	2 A	57.0	4 A	50.4
2	3 B	52.7	1 A	55.0	16 A	48.9
3	15 C	44.0	5 A	53.8	3 A	48.1
4	13 C	41.1	16 B	51.4	1 B	45.3
5	28 C	40.4	24 B	49.0	2 B	45.3
6	2 D	38.7	19 B	48.3	13 B	42.6
7	6 D	38.4	3 B	48.0	19 C	40.4
8	7 D	37.6	27 B	47.9	5 C	40.0
9	18 D	36.4	4 C	43.0	24 C	39.2
10	14 D	35.3	29 C	42.7	18 C	37.3
11	16 D	34.9	13 C	41.3	27 D	34.5
12	1 D	34.7	23 C	41.3	23 D	33.6
13	5 D	34.7	18 D	35.5	29 D	32.7
14	24 D	33.5	12 D	33.2	28 E	28.9
15	23 E	20.6	11 E	29.8	12 F	25.4
16	12 E	29.9	6 F	23.0	6 F	23.3
17	29 F	27.0	28 F	21.0	15 F	22.4
18	27 F	26.9	9 G	15.0	7 G	20.1
19	20 F	24.4	22 G	14.0	14 G	19.2
20	10 G	17.7	21 H	8.8	22 H	15.1
21	9 G	16.9	14 H	8.3	11 H	14.9
22	19 G	16.9	20 H	6.3	20 H	14.9
23	11 H	4.4	7 H	6.0	9 H	13.5
24	22 H	3.4	10 H	5.7	10 I	11.3
25	21 H	1.7	15 I	2.9	21 I	11.1
$\bar{X}$±SE		30.5±2.9		31.5±3.7		30.3±2.6

---

[1] STANDING DEAD

[2] LIVE + STANDING DEAD

[3] Those location numbers in the same column followed by the same letter were determined by SAS79 Cluster Analysis (Helwig and Council 1979) to be within relatively homogeneous clusters.

TABLE 42. AVERAGE CHEMICAL COMPOSITION (%) OF CATTLE DUNG DEPOSITED IN DIFFERENT SEASONS AND COLLECTED AFTER DIFFERENT PERIODS OF TIME ON A TALLGRASS PRAIRIE WATERSHED GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-78

Degradation Period (Days)	Deposition Season					
	7/76	7/77	9/77	1/78	5/78	Mean[1]
			NITROGEN			
0	1.92	1.40	--[2]	1.35	2.29a[3]	1.83a
15	--	1.39	1.33	--	--	1.37b
30	1.91	1.44	1.23	--	1.79b	1.61ab
60	2.15	1.43	1.35	1.22	1.75b	1.58b
90	--	1.75	1.42	1.23	1.54b	1.49b
120	1.72	1.50	1.47	1.21	--	1.48b
180	1.65	--	1.38	1.28	--	1.44b
240	2.21	1.24	1.44	1.24	--	1.49b
P[4]	0.07	0.23	0.51	0.67	0.01	0.01
			PHOSPHORUS			
0	0.21	0.08c	--	0.16c	0.19b	0.11c
15	--	0.30a	0.13	--	--	0.22ab
30	0.24	0.31a	0.18	--	0.52a	0.25ab
60	0.27	0.20b	0.19	0.21ab	0.44a	0.21bc
90	--	0.31a	0.24	0.25a	0.44a	0.31a
120	0.20	0.20b	0.20	0.19bc	--	0.15c
180	0.22	--	0.20	0.15c	--	0.12c
240	0.26	0.16bc	0.19	0.15c	--	0.14c
P	0.18	0.01	0.37	0.01	0.01	0.01
			POTASSIUM			
0	0.50a	0.50a	--	0.49a	1.15a	0.70a
15	--	0.30bc	0.37a	--	--	0.33b
30	0.29b	0.27bc	0.38a	--	0.21b	0.29b
60	0.27b	0.39ab	0.25b	0.30b	0.23b	0.29b
90	--	0.27bc	0.26b	0.33b	0.25b	0.28b
120	0.20b	0.16c	0.25b	0.23bc	--	0.21bc
180	0.17b	--	0.20b	0.14c	--	0.17c
240	0.21b	0.22c	0.17b	0.25b	--	0.21bc
P	0.01	0.01	0.01	0.01	0.01	0.01

(Continued)

TABLE 42 (Continued)

Degradation Period (Days)	Deposition Season 7/76	7/77	9/77	1/78	5/78	Mean[1]
			CALCIUM			
0	1.39	1.03	--	1.34a	1.48	1.37a
15	--	0.99	1.15	--	--	1.06bc
30	1.27	1.00	0.92	--	1.30	1.13b
60	1.44	0.75	1.07	0.90b	1.24	1.08b
90	--	1.01	0.97	0.93b	1.25	1.04bc
120	1.07	0.93	1.08	0.75b	--	0.96bc
180	1.23	--	0.89	0.86b	--	1.00bc
240	1.24	0.78	0.87	0.71b	--	0.88c
P	0.23	0.24	0.26	0.01	0.13	0.01

---

[1] Average weighted by number of samples per deposition season and degradation period.

[2] Dung sample not collected or not analyzed.

[3] Those values in the same column followed by the same letter are not significantly different at the 0.05 level.

[4] Probability level.

slight decrease in N content over time. Essentially, those factors influencing the N content of dung at the time of deposition strongly outweigh environmental factors influencing loss of N after deposition.

The phosphorus content in dung also varied due to season of deposition and period of time subject to degradation. In general, P concentration increased during the first 30 to 90 days after deposition and decreased after about 90 days in place. Apparently, since P is relatively immobile, the actual amount of P remains relatively constant, but other material in dung decreases. Then, either P is mobilized and moved out of the dung or P-bearing material is moved out of the dung. P contents due to season of deposition did not vary as much as did N contents.

The change in potassium contents over time was much more consistent than those of N and P contents. K content decreased rapidly in the first 15 to 30 days in place, then stabilized over the remainder of the period.

Changes in calcium content in dung over time were similar to those of K content. However, the relative loss of CA over time was not as great as that of K.

Changes in concentrations of structural fiber components (i.e., acid-detergent fiber, acid-detergent lignin, and cellulose) were determined over a 240-day degradation period for dung deposited in July 1976 (Table 43). Fiber and lignin tended to increase over time, whereas cellulose decreased over time.

TABLE 43. AVERAGE FIBER COMPONENTS (%) OF DUNG (0-240 DAYS) DEPOSITED JULY 1976 ON A TALLGRASS PRAIRIE WATERSHED GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA

Degradation Period (Days)	Acid-Detergent Fiber (%)	Acid-Detergent Lignin (%)	Cellulose (%)
0	46.8c[1/]	18.1c	23.0a
30	47.5c	17.3c	21.8b
60	50.7b	21.2a	20.8c
120	55.0a	19.0bc	18.0d
180	54.4a	20.5ab	18.7d
240	53.9a	21.7a	19.4cd

[1/] Those values in the same column followed by the same letter are not significantly different at the 0.05 level.

Regardless of the nutrient in question, changes in chemical concentration over time were not great. Although a certain percentage of the initial chemical content was leached, volatilized or otherwise moved out of the dung pat, dung decomposition appears to be affected more by fragmentation and incorporation into the soil by decomposers.

Changes in dung pat weight over time were not determined. However, this area of dung degradation research should be studied. Based on variation in the degradation of different dung pats observed on the watershed, future research will no doubt require sampling a large number of dung pats deposited in different seasons. Weeda (1967) reported dung deposited in the fall disappeared more rapidly than dung deposited in the spring or early summer. Castle and MacDaid (1972) found dung deposited on N-fertilized pastures disappeared significantly faster in July than that deposited in May.

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APPENDIX A

SOIL DESCRIPTIONS FOR WATERSHED SOILS

CLASSIFICATION AND CORRELATION OF THE SOILS OF ENVIRONMENTAL RESEARCH WATERSHED OF NOBLE COUNTY, OKLAHOMA

The 137 acres of the Environmental Research range are located primarily in the NW¼ and the N½ of the SW¼ of Section 32, T20N, R1E, Noble County, Oklahoma. The Soil Survey was made by personnel of project 1383 under direction of Earl C. Nance, Soil Scientist, USDA, retired, January 1976. Also, several students in soil morphology courses were involved with the survey.

Inclusions are a normal part of the mapping units. Where data is to be obtained from a location, the soil should be described and named at that location. The approximate scale of mapping is 1:7920 (or 8 inches per mile).

The upland soils on the station are developed in materials weathered from alternating layers of shale and sandstone. Lithologic discontinuities are common with the upper part of the solum developed in materials weathered from sandstones and the lower part developed in materials weathered from shales (Fenton Gray, 51383 Project Leader, 1976).

Aydelotte loam, 3 to 6 percent slopes, Soil No. 1

About half of these soils have 102-153 cm solum thickness and are outside the range of the series. The remainder have more than 153 cm solum thickness to bedrock. In many areas the upper 25-50 cm of the solum is developed from sandstone and the lower part is developed from shale.

Representative Pedon:

A1 -- 0 - 13 cm -- Dark brown (7.5YR 3/2); loam; weak medium granular structure; friable; neutral; clear smooth boundary.

B1 -- 13 - 25 cm -- Brown (7.5YR 4/2); loam; moderate medium granular structure; friable; slightly acid; abrupt smooth boundary.

Cr -- 25 - 28 cm -- Strong brown (7.5YR 5/6); fractured, bedded, paralithic sandstone; neutral; abrupt smooth boundary.

IIB12 -- 28 - 36 cm -- Reddish brown (5YR 4/4); loam; weak fine subangular blocky structure; friable; neutral; abrupt smooth boundary.

IIB21t -- 36 - 48 cm -- Reddish brown (2.5YR 4/4); silty clay; weak fine blocky structure; very firm; neutral; shiny ped surfaces; gradual smooth boundary.

IIB22t -- 48 - 76 cm -- Reddish brown (2.5YR 4/4); silty clay; weak medium blocky structure; very firm; moderately alkaline; shiny ped surfaces; few fine black bodies; gradual smooth boundary.

IIB3 -- 76 - 152 cm -- Red (2.5YR 4/6); silty clay; weak fine blocky structure; very firm; moderately alkaline; very firm; shiny ped surfaces; few fine black bodies; few gypsum crystals.

Range in characteristics: Solum thickness ranges from 102 to more than 153 cm. Thin paralithic beds of fractured sandstone are present in any part of the solum in some areas. The A1 horizon colors are dark brown (7.5YR 3/2) or dark reddish brown (5YR 3/3). Reaction is slightly acid or neutral. The IIB2t or B2t horizon where present, colors are reddish brown (5YR 4/4; 2.5YR 4/4). Textures are silty clay or clay. Reaction ranges from slightly acid through mildly alkaline. The IIB3 or B3 horizon colors are reddish brown (2.5YR 4/4) or red (2.5YR 4/6). The Cr or IICr horizon is thin paralithic seams of fractured sandstone and thick bedded shales. Included with these soils in mapping are small areas of Grainola and Stoneburg soils and slick-spot (sodium) soils.

Darnell fine sandy loam, 3 to 6 percent slopes, Soil No. 2

These soils have cambic horizons, that are close to minimal argillic horizon in some areas.

Representative pedon

A1 -- 0 - 12 cm -- Brown (10YR 5/3); fine sandy loam; weak fine granular structure; very friable; slightly acid; clear smooth boundary.

B2 -- 12 - 40 cm -- Brown (7.5YR 5/4); fine sandy loam; weak fine granular structure; very friable; medium acid; clear smooth boundary.

Cr -- 40 - 51 cm -- Strong brown (7.5YR 5/6); paralithic bedded sandstone; fractured; roots penetrate these sandstone beds in fractures; slightly acid.

Range in characteristics: Solum thickness is 25 to 50 cm. A1 horizon colors are brown (10YR 5/3; 7/5YR 4/2, 4/3) very dark greyish brown (10YR 3/2) or reddish brown (5YR 4/3). Reaction is slightly or medium acid. The B2 horizon colors are dark yellowish brown (10YR 4/4), brown (7.5YR 4/4, 5/4), strong brown (7.5YR 5/6), reddish brown (5YR 4/4, 5/4) or yellowish red (5YR 5/6). Reaction ranges from medium acid through neutral. The Cr horizon is bedded sandstone of varying thickness. Colors are shades of brown or red. Included with these soils in mapping are small areas of Stephenville soils, rock outcrops and soil similar to Darnell except the solum has loamy sand texture.

Darnell-Rock outcrop complex, 1 to 8 percent slopes, Soil No. 3

These soils and sandstone rock-outcrops occur in an intricate pattern that is not practical to separate at the scale selected for mapping. Darnell soils make up about 90 percent, rock outcrops make up about 5 percent and other soils make up about 5 percent of the mapped area. Darnell soils in this mapping unit typically have less than 25 cm of solum thickness and are outside the range of the series. However, the use and management of these soils are similar to Darnell soils.

Representative Pedon

A1 -- 0 - 15 cm -- Brown (7.5YR 4/4); fine sandy loam; weak fine granular structure; very friable; slightly acid; clear smooth boundary.

Cr -- 15 - 25 cm -- Strong brown (7.5YR 5/6); paralithic, fractured bedded sandstone; slightly acid, textures to sandy loam; roots penetrate in fractures.

Range in characteristics: Solum thickness is 8 to 50 cm. The A1 horizon colors are brown (10YR 5/3; 7.5YR 4/2, 4/4), dark grayish brown (10YR 4/2) or reddish brown (5YR 4/3). Reaction is slightly or medium acid. Where present, the B2 horizon colors are shades of brown or red in hues 10YR, 7.5YR or 5YR. The texture is fine sandy loam and reaction ranges from medium acid through neutral. The Cr horizon colors are shades of red or brown, fractured, bedded sandstone. Rock outcrops are sandstone bedrock exposed at the surface or protruding above the surface.

Included in mapping are small areas of Stephenville soils and soils similar to Darnell soils except the solums are loamy fine sand.

Grainola loam, 0 to 3 percent slopes, Soil No. 4

The A1 horizons are developed from sandstone and the IIBt horizons are dominantly developed from shales. These soils are outside the series range because of the A1 horizon's loam texture and the reaction of the A and upper B horizons. However, their use and management are similar to Grainola soils.

Representative Pedon

A1 -- 0 - 7 cm -- Dark brown (7.5YR 3/2); loam; weak fine granular structure; friable; slightly acid; clear smooth boundary.

IIB21t -- 7 - 20 cm -- Dark reddish brown (5YR 3/4); silty clay; moderate fine blocky structure; very firm; neutral; shiny ped surfaces; few vertical faces are coated with brown loam; clear smooth boundary.

IIB22t -- 20 - 35 cm -- Reddish brown (5YR 4/4); silty clay; weak fine blocky structure; very firm; mildly alkaline; shiny ped surfaces; few vertical faces are coated with brown loam; gradual smooth boundary.

IIB23t -- 35 - 46 cm -- Reddish brown (5YR 4/4) silty clay; weak fine blocky structure; very firm; moderately alkaline; shiny ped surfaces; few fine $CaCO_3$ and Fe-Mn oxide concretions; clear smooth boundary.

IIB3 -- 46 - 61 cm -- Reddish brown (5YR 4/4); silty clay and shale; weak coarse blocky structure; very firm; moderately alkaline; clear smooth boundary.

IICr -- 61 - 76 cm -- Moderately alkaline shale with thin lens of sandstone; few gypsum crystals.

Range in characteristics: Solum thickness is typically 50 to 75 cm but ranges 50 to 100 cm. A Cr horizon of thinly bedded sandstone is present between the A1 and IIBt horizons in some areas. The A1 horizon colors are dark brown (7.5YR 3/2), dark reddish brown (5YR 3/2, 3/3, 3/4) and reddish brown (5YR 4/3). The texture is dominantly loam; however a few areas of silty clay loam are present. Reaction ranges from slightly acid through mildly alkaline. The B1 horizon, where present, colors are brown (7.5YR 4/2), reddish brown (5YR 4/4, 4/3) or yellowish red (5YR 4/6). Textures are loam or clay loam and reaction ranges from slightly acid through neutral. The IIB2t horizon colors are dark reddish brown (5YR 3/3, 3/4; 2.5YR 3/4), or reddish brown (5YR 4/4; 2.5YR 4/4). Textures are clay, silty clay or silty clay loam. Reaction ranges from slightly acid through moderately alkaline. The IIB3 horizon, where present, colors are reddish brown (5YR 4/4; 2/5YR 4/4). Textures are silty clay or clay. Reaction ranges from mildly through moderately alkaline. The IICr horizon is shale with thin lens of sandstone. Colors are shades of red, brown, or gray.

Included in mapping are small areas of similar soils that have less than 51 cm of solum thickness, Lucien soils, and soils similar to Grainola except the IIBt horizons are brown sandy clay. Also included are a few slick-spot (sodium) soils.

Grainola loam, 3 to 6 percent slopes, Soil No. 5

The A1 horizons and in some areas the upper B horizons are developed from sandstone; and the IIBt horizons are developed from shale. These soils are outside the series range because of the A1 horizon texture and the reaction of the A and upper B horizons. However their use and management are similar to Grainola soils.

Representative Pedon

A1 -- 0 - 12 cm -- Dark reddish brown (5YR 3/3); loam; weak medium granular structure; friable; neutral; clear smooth boundary.
IIB1 -- 12 - 23 cm -- Dark reddish brown (5YR 3/3); silty clay loam; weak fine blocky structure; firm; mildly alkaline; some vertical faces coated with loam texture; clear smooth boundary.
IIB21t -- 23 - 41 cm -- Dark reddish brown (2.5YR 3/4); silty clay; moderate fine blocky structure; very firm; mildly alkaline; shiny ped surfaces; gradual smooth boundary.
IIB22t -- 41 - 86 cm -- Dark reddish brown (2.5YR 3/4); silty clay; weak medium blocky structure; very firm; moderately alkaline; shiny ped surfaces; few seams and bodies of $CaCo_3$; few slickensides do not intersect; abrupt smooth boundary.

IICr -- 86 - 152 cm -- Shales with lens of fractured hard and soft sandstone.

Range in characteristics: Solum thickness is 51 to 102 cm. A Cr horizon of thinly bedded, paralithic sandstone is present above the IIBt horizon in some areas. The A1 horizon colors are dark reddish brown (5YR 3/2, 3/3, 3/4), reddish brown (5YR 4/3) and dark brown (7.5YR 3/2). Reaction ranges from slightly acid through neutral. A B1 or B2t horizon is present in some areas. Colors are shades of brown or red. Textures are loam or clay loam and reaction ranges from slightly acid through neutral.

The IIB1 and IIB2t horizons colors are dark reddish brown (5YR 3/3, 3/4; 2.5YR 3/4), reddish brown (5YR 4/3, 4/4; 2.5YR 4/4) or red (2.5YR 4/6). Textures are clay, silty clay or silty clay loam. Reaction ranges from slightly acid through moderately alkaline. The B3 horizon, where present, colors are reddish brown (5YR 4/4; 2.5YR 4/4). Textures are silty clay or clay and reaction is mildly or moderately alkaline. The IICr horizon colors are shades of red or brown. It is shale with thin layers of sandstone.

Included in mapping are small areas of Aydelotte, Renfrow, Stoneburg, and Lucien soils and soils similar to Grainola with less than 51 cm solum thickness and soils similar to Grainola except the upper, (sandstone), part of the solum is 38 to 63 cm thick.

Lucien sandy loam, 1 to 3 percent slopes, Soil No. 6

These soils are outside the range of the series in that the solum thickness is less than 25 cm or they lack a mollic epipedon. In typical areas, the cambic horizon is close to being a minimal argillic horizon. However all of these soils respond to use and management of the Lucien series.

Representative Pedon

A1 -- 0 - 8 cm -- Dark brown (7.5YR 3/3); sandy loam; weak fine granular structure; very friable; slightly acid; clear smooth boundary.
B21 -- 8 - 18 cm -- Brown (7.5YR 4/4); sandy loam; weak coarse prismatic and granular structure; friable; slightly acid; clear smooth boundary.
B22 -- 18 - 38 cm -- Reddish brown (5YR 4/4); sandy loam; weak coarse subangular blocky structure; friable; slightly acid; few pale brown (10YR 6/3) sandstone fragments; clear smooth boundary.
Cr1 -- 38 - 61 cm -- Reddish yellow (7.5YR 6/6); paralithic; fractured sandstone; slightly acid; roots in bedding planes; diffuse boundary.
Cr2 -- 61 - 84 cm -- Stratified reddish yellow (7.5YR 6/6) and light brownish gray (10YR 6/2) sandstone; few roots in bedding planes.
Cr3 -- 84 - 97 cm -- Stratified sandstone and thin lens of sandy clay; no visible roots.

Range in characteristics: Solum thickness is 8 to 51 cm. The A1 horizon colors are dark brown (7.5YR 3/2, 3/3) or dark reddish brown (5YR 3/2, 3/3). Sandy loam is the dominant texture; however, areas of loam do occur. Reaction is slightly or medium acid. The B2 horizon colors are brown (7.5YR 4/2, 4/2, 5/4), reddish brown (5YR 4/4; 2.5YR 4/4) or yellowish red (5YR 4/6).

Textures are sandy loam or loam and reactions are slightly or medium acid. The Cr horizon colors are shades of brown, red or yellow. Included in mapping are small areas of Stoneburg and Grainola soils and rockout crops.

Lucien loam, 3 to 5 percent slopes, Soil No. 7

About one-third of the Lucien soils lack thickness for mollic epipedons, and these are outside the series range. Typically these soils are within the range of the Lucien series.

Representative Pedon

A1 -- 0 - 12 cm -- Dark brown (7.5YR 3/2); loam; weak medium granular structure; friable; slightly acid; thin ½ inch paralithic sandstone at base; abrupt clear boundary.
B2 -- 12 - 33 cm -- Brown (7.5YR 4/4); loam; weak coarse prismatic breaking to granular structure; friable; slightly acid; clear smooth boundary.
Cr -- 33 - 63 cm -- Light yellowish brown (10YR 6/4); paralithic, fractured bedded sandstone; neutral; roots in bedding planes.

Range in characteristics: Solum thickness is 25 to 51 cm. The A1 horizon colors are dark brown (7.5YR 3/2) or dark reddish brown (5YR 3/2, 3/3). Reaction is slightly or medium acid. The B2 horizon colors are brown (7.5YR 4/2, 4/4, 5/4), reddish brown (5YR4/4) or yellowish red (5YR 4/6). Reaction is slightly or medium acid. The Cr horizon colors are shades of brown or red.

Included with these soils in mapping are small areas of Stoneburg or Grainola soils and rock outcrops. Also included are soils similar to Lucien with less than 25 cm of solum thickness or lack a mollic epipedon.

Lucien loam, 5 to 8 percent slopes, Soil No. 8

These soils are typically within the range of the Lucien series.

Representative Pedon

A1 -- 0 - 12 cm -- Dark brown (7.5YR 3/2); loam; weak fine granular structure; very friable; slightly acid; clear smooth boundary.
B2 -- 12 - 33 cm -- Brown (7.5YR 4/4); loam; weak medium granular structure; friable; slightly acid; clear smooth boundary.
Cr -- 33 - 66 cm -- Brown (7.5YR 5/4); paralithic sandstone; neutral; roots throughout upper part but confined to bedding planes in lower part.

Range in characteristics: Solum thickness is 25 to 51 cm. The A1 horizon colors are dark brown (7.5YR 3/2) or dark reddish brown (5YR 3/2, 3/3). Textures are loam or sandy loam and reactions are medium or slightly acid. The B2 horizon colors are brown (7.5YR 4/2, 4/4, 5/4), reddish brown (5YR 4/4) or yellowish red (5YR 4/6). Textures are sandy loam or loam and reactions are medium or slightly acid. The Cr horizon colors are shades of brown or red. Included with these soils in mapping are small areas of Zaneis or Stoneburg soils.

Lucien - Rock outcrop complex, 8 to 30 percent slopes, Soil No. 9

These soils and sandstone rock outcrops occur in an intricate pattern that is not practical to separate at the scale selected for mapping. Lucien soils make up about 50 percent, rock outcrops about 30 percent and other soils about 20 percent of the mapped area. Lucien soils in this mapping unit typically have less than 25 cm of solum thickness and are outside the series range. However, the use and management of these soils will be similar to Lucien soils.

Representative Pedon

A1 -- 0 - 7 cm -- Dark brown (7.5YR 3/2); sandy loam; weak fine granular structure; very friable; slightly acid; clear smooth boundary.
AC -- 7 - 15 cm -- Brown (7.5YR 4/4); sandy loam; weak fine granular structure; very friable; slightly acid; clear smooth boundary.
Cr -- 15 - 33 cm -- Brown (7.5YR 5/4); paralithic, bedded sandstone; few roots in bedding planes.

Range in characteristics: Solum thickness is typically 8 to 25 cm but ranges from 8 to 51 cm. The A1 horizon colors are dark brown (7.5YR 3/2, 3/3). Textures are dominantly sandy loam but include loam. Reaction is slightly or medium acid. The AC horizon colors are brown (7.5YR 4/2, 4/4, 5/4). Textures are sandy loam or loam and reactions are slightly or medium acid. The Cr horizon colors are shades of brown.

Included with these soils and rock outcrop in mapping are small areas of Stoneburg and Grainola soils. Also included are soils gradational in development between Lucien and Stoneburg or Grainola soils.

Renfrow loam, 3 to 5 percent slopes, Soil No. 10

These soils occur on side slopes and are developed in material weathered from shales. These shales are interrupted by bedded sandstones of varying thickness. These soils are outside the range of the Renfrow series because of the B3 horizon colors. However, these soils will respond to management like Renfrow soils.

Representative Pedon

A1 -- 0 - 38 cm -- Dark brown (7.5YR 3/2); loam; moderate, medium granular structure; friable; slightly acid; clear smooth boundary.
B1 -- 38 - 58 cm -- Reddish brown (5YR 4/3); clay loam; moderate, medium subangular blocky structure; firm; slightly acid; gradual smooth boundary.
B21t -- 58 - 81 cm -- Reddish brown (5YR 4/3); silty clay; moderate, medium blocky structure; very firm; mildly alkaline; clay films on slightly darker ped surfaces; few fine Fe-Mn oxide concretions; gradual smooth boundary.

B22t -- 81 - 127 cm -- Reddish brown (5YR 4/4); silty clay; weak coarse blocky structure; very firm; moderately alkaline; clay films on ped surfaces; few, medium $CaCO_3$ bodies; diffuse smooth boundary.
B3 -- 127 - 158 cm -- Reddish brown (5YR 4/4); clay loam high in sand; few fine distinct yellowish red (5YR 5/6) mottles; weak coarse blocky structure; very firm; moderately alkaline; few medium $CaCO_3$ bodies.

Range in characteristics: The extent of these soils is too limited to establish a range in characteristics. Included with these soils are small areas of Grainola soils and slick-spot soils.

Stephenville sandy loam, 3 to 6 percent slopes, Soil No. 11

These soils are within the Stephenville series. However, their solum thickness is typically less than normal for the series.

Representative Pedon

A1 -- 0 - 8 cm -- Dark brown (7.5YR 3/2); sandy loam; weak fine granular structure; very friable; slightly acid; clear smooth boundary.
A2 -- 8 - 30 cm -- Brown (7.5YR 5/4); sandy loam; weak fine granular structure; very friable; medium acid; clear smooth boundary.
B2t -- 30 - 58 cm -- Reddish brown (5YR 5/4); sandy clay loam; weak fine subangular blocky structure; firm; medium acid; clay films on ped surfaces; clear smooth boundary.
Cr -- 58 - 76 cm -- Strong brown (7.5YR 5/6); paralithic sandstone; roots throughout the matrix in upper part, but confined to fractures and bedding planes in lower part; slightly acid.

Range in characteristics: Solum thickness is typically 51 to 76 cm but ranges from 51 to 102 cm. The A1 horizon colors are dark brown or brown (7.5YR 3/2, 4/2). The A2 horizon colors are brown (7.5YR 4/4, 5/4) or reddish brown (5YR 4/4, 5/4). Reaction is slightly or medium acid. The B2t horizon colors are reddish brown (5YR 4/4, 5/4) or yellowish red (5YR 4/6). Textures are sandy clay loam or loam and reaction is medium or slightly acid. The B3 horizon, where present, is similar in color, texture and reaction to the B2t horizon. The Cr horizon colors are shades of red or brown. Included with these soils in mapping are small areas of Darnell soils and soils similar to Stephenville except the solum thickness is more than 102 cm.

Stoneburg loam, 1 to 3 percent slopes, Soil No. 12

These soils are outside the Stoneburg series range of characteristics in that they lack mollic epipedons.

Representative Pedon

A1 -- 0 - 16 cm -- Dark brown (7.5YR 3/3); loam; moderate medium granular structure; friable; slightly acid; clear smooth boundary.

B21t -- 16 - 36 cm -- Dark brown (7.5YR 3/4); clay loam; weak medium subangular blocky structure; firm; slightly acid; clay films on ped surfaces; clear smooth boundary.

B22t -- 36 - 53 cm -- Yellowish red (5YR 5/6); clay loam; weak medium subangular blocky structure; firm; slightly acid; clay films on ped surfaces; clear smooth boundary.

R or Cr -- 53 cm -- Sandstone - unable to auger for color, reaction and hardness.

Range in characteristics: Extent too small for establishing range in characteristics. Included with these soils in mapping are small areas of Grainola and Lucien soils and soil gradational in development between Stoneburg and Grainola. Also included are small areas of soils similar to Stoneburg with less than 20 inches solum thickness.

Stoneburg loam, 3 to 6 percent slopes, Soil No. 13

These soils are outside the range of Stoneburg series in that they lack a mollic epipedon and some of the solum colors are slightly outside the series range. However, these soils' responses to management are similar to those of the Stoneburg soils.

Representative Pedon

A1 -- 0 - 15 cm -- Dark brown (7.5YR 3/2); loam; moderate medium granular structure; friable; slightly acid; clear smooth boundary.

B1 -- 15 - 31 cm --Dark reddish brown (5YR 3/4); loam; weak coarse subangular blocky structure; friable; slightly acid; gradual smooth boundary.

B2t -- 31 - 46 cm -- Reddish brown (5YR 4/4); clay loam; weak medium subangular blocky structure; firm; slightly acid; clay films on ped surfaces; diffuse smooth boundary.

B3 -- 46 - 64 cm -- Reddish brown (5YR 4/4); loam; weak coarse subangular blocky structure; firm; slightly acid; clear smooth boundary.

Cr & R -- 64 - 100 cm -- Yellowish red (5YR 5/6); neutral sandstone; roots penetrate the matrix of the upper part but occur only in fractures and bedding planes in lower part.

Range in characteristics: Solum thickness is 51 to 102 cm. The A1 horizon is dark brown (7.5YR 3/2, 3/3, 4/2) or dark reddish brown (5YR 3/3). Reactions are slightly acid or neutral. The B1 horizon, where present, is brown (7.5YR 4/4), reddish brown (5YR 4/3, 4/4) or dark reddish brown (5YR 3/3, 3/4). Textures are loam or sandy clay loam and reactions are slightly acid or neutral. The B2t horizon colors are brown (7.5YR 4/4, 5/4) or reddish brown (5YR 4/3, 4/4, 5/4; 2.5YR 4/4, 5/4). Textures are clay loam or loam and reactions are slightly acid or neutral. The B3 horizon, where present, has colors, textures and reactions similar to those in the B2t horizons. The Cr horizon or R layer are bedded sandstones with colors in shades of brown.

Included with these soils in mapping are small areas of Aydelotte, Lucien, Grainola, and Zaneis soils. Also included are soils that are gradational in development between Stoneburg and Grainola over shales.

Stoneburg - Channel complex, 1 to 30 percent slopes, Soil No. 14

These soils and channel occur in an intricate pattern that is not practical to separate at the scale selected for mapping. They occur on drainageways and are dominantly developed in materials weathered from stratified edges of shales and sandstones. There are many soils in this mapping unit; and most of them are outside the named series range of characteristics. Upland soils occur on 82 percent of the area; and their average slope is 16 percent. Floodplain soils occur on 10 percent of the area; on 0 to 1 percent slopes. Channel (stream channels) occupy about 8 percent of the area.

The approximate composition of the mapping unit will be listed, along with the reason those soils are outside the named series range. Stoneburg will be the only soil described. For a description or range or engineering interpretation of the named soils refer to the series description.

1. Stoneburg soils occur on 9 to 25, average 17 percent slopes and make up 28 percent of the mapping units. These soils lack mollic epipedons of the Stoneburg series; and slopes exceed those allowed in the series. However, their response to range and engineering uses are similar to Stoneburg soils.

2. Stoneburg soils over clay occur on 18 to 25 percent slopes, average 22 percent slopes; and make up 4 percent of the mapping unit. These soils lack mollic epipedons, slopes exceed those allowed and the lower subsoil is more clayey than Stoneburg soils. Permeability rate is 0.06 to 0.20 inches per hour when the soil is at field capacity. Refer to the Stoneburg series for use and management information.

3. Zaneis soils occur on 7 to 20, average 12 percent slopes; and occupy 17 percent of the area. Typically these soils lack bedrock within 153 cm of the surface, that is present in the Zaneis soils. Refer to the Zaneis series of use and management information.

4. Zaneis soils over clay occur on 3 to 5, average 4 percent slopes; and occupy 6 percent of the area. Typically these soils lack bedrock within 153 cm of the surface, that is present in the Zaneis soils. The clayey, lower subsoil is outside the series range. The permeability rate is 0.06 to 0.20 inches per hour when the soil is at field capacity. Refer to the Zaneis series for use and management information.

5. Grainola soils occur on 15 to 25, average 21 percent slopes; and occupy 13 percent of the area. These soils are outside the series range because of the A1 horizon texture and the reaction of the A1 and upper B horizons. However, their use and management for range and engineering are similar to Grainola soils.

6. Lucien soils occur on 15 to 25, average 20 percent slopes and occupy 4 percent of the area. Some of the slopes exceed those allowed in the Lucien series. Refer to the Lucien series for range and engineering use and management information.

7. Noble soils occur on 15 to 30, average 23 percent slopes; and occupy about 4 percent of the area. These soils are outside the series in that they have more than 60 inches of solum thickness and slopes exceed those allowed in the series. Refer to the Noble series for use and management information.

8. Stephenville soils occur on 10 to 30, average 20 percent slopes; and occupy about 4 percent of the area. The slopes are typically outside the range of the series. Refer to the Stephenville series for range and engineering information.

9. Aydelotte soils occur on 15 percent slopes and occupy 2 percent of the area. The slopes are outside the series range. However, the use and management information for range and engineering will apply to these soils.

10. Channel (Creek channels) are approximately 1.5 to 4.0 m wide and 0.6 to 1.4 m deep. They occupy about 8 percent of the area. Slopes are 0 to 1 percent.

11. Pulaski soils occur on 0 to 1 percent flood plains. The control section, 0.25 to 1.0 m, averages sandy loam. These soils occupy about 4 percent of the area and are within the Puluski series.

12. Port soils occur on 0 to 1 percent slopes in the flood plains. They occupy about 4 percent of the area. The thickness of the mollic epipedon is not cumulic in all areas. The control section exceeds 15 percent fine sand or coarser in some areas. However their use and management is similar to Port soils.

13. Aquic Udifluvents, fine-loamy, mixed, thermic - no known series for this part of Oklahoma. (Tullahassee soils are similar but slightly less clayey.) These soils occur on 0 to 1 percent flood plains; and occupy about 2 percent of the area.

Stoneburg soils are outside the range of the series in that they lack a mollic epipedon, slopes exceed the allowable range and some of the solum colors are outside the series range. However, their use and management for range and engineering are similar to Stoneburg soils.

Representative Pedon Stoneburg; moist colors

A1 -- 0 - 10 cm -- Dark brown (7.4YR 3/2); sandy loam; weak fine granular structure; very friable; slightly acid; clear smooth boundary.

B1 -- 10 - 41 cm -- Reddish brown (5YR4/4); sandy loam; weak coarse prismatic structure; very friable; slightly acid; clear smooth boundary.

B21t -- 41 - 64 cm -- Yellowish red (5YR 4/6); sandy clay loam; weak coarse prismatic structure; friable; slightly acid; thin clay films on ped surfaces and sand grains; gradual smooth boundary.

B22t -- 64 - 84 cm -- Yellowish red (5YR 4/6); sandy clay loam; weak coarse subangular blocky structure; friable; slightly acid; thin clay films on ped surfaces; few fine black bodies; clear smooth boundary.

R -- 84 cm - Sandstone too hard for auger to penetrate.

Range in characteristics: Solum thickness is 50 to 100 cm. The A1 horizon colors are dark brown (10YR 3/3; 7.5YR 3/2, 4/2, 4/3), dark reddish brown (5YR 3/3) or reddish brown (5YR 4/3). Textures are sandy loam or loam and reactions are slightly acid or neutral. The B1 horizon where present, colors are brown (7.5YR 4/4, 4/3) or reddish brown (5YR 4/4). The B2t horizon colors are brown (7.5YR 4/3, 4/4), reddish brown (5YR 4/4; 2.5YR 4/4) or yellowish red (5YR 4/6). Textures are sandy clay loam or loam and reactions are slightly acid or neutral.

Zaneis loam, 3 to 6 percent slopes, Soil No. 15

These soils are outside the range of the Zaneis series in that they lack a mollic epipedon, have a clayey lower argillic horizon or solum thickness is more than 153 cm. However these soils respond to range and agronomic use and management similar to the Zaneis soils. For engineering use and management refer to the Zaneis and Renfrow series; that is, use the Renfrow data for the clayey lower argillic horizon.

Representation Pedon

A1 -- 0 - 23 cm -- Dark brown (7.5YR 3/2); loam; weak fine granular structure; friable; slightly acid; clear smooth boundary.

B1 -- 23 - 41 cm -- Reddish brown (5YR4/4); loam; moderate medium granular structure; friable; slightly acid; gradual smooth boundary.

B21t -- 41 - 59 cm -- Reddish brown (2.5YR 4/4); sandy clay loam; weak coarse prismatic breaking to weak medium granular structure; friable; slightly acid; clay films on ped surfaces; gradual smooth boundary.

B22t -- 59 - 89 cm -- Reddish brown (2.5YR 4/4); clay loam; weak coarse prismatic breaking to weak coarse subangular blocky structure; firm; slightly acid; clay films on ped surfaces; few iron stains on ped surfaces; abrupt smooth boundary.

IIB23t -- 89 -147 cm -- Reddish brown (5YR 5/4); silty clay; moderate, medium blocky structure; very firm; neutral; clay films on ped surfaces; few light brownish gray (2.5 YR 6/2) streaks and bodies in lower part; clear smooth boundary.

IICr --147 -165 cm -- Reddish brown (2.5YR 5/4); bedded shale; mildly alkaline; few roots in bedding planes.

Range in characteristics: Solum thickness is 100 to more than 150 cm and thickness to the IIBt horizon is 75 to 115 cm. The A1 horizon colors are dark brown (7.5YR 3/2, 3/3, 4/2) or dark reddish brown (5YR 3/2, 3/3). Reactions are medium or slightly acid. The B1 horizon where present, colors are reddish brown (5YR 4/4) or dark reddish brown (5YR 3/4; 2.5YR 3/4). Textures are clay loam, sandy clay loam or loam. Reactions are slightly acid or neutral. The B2t horizon colors are reddish brown (5YR 4/4; 2.5YR 4/4) or yellowish red (5YR 4/6). Textures are sandy clay loam or clay loam. Reactions are slightly acid or neutral. The IIBt horizon colors are reddish brown (5YR 4/4, 5/4; 2.5YR 4/4) or yellowish red (5YR 4/6). Textures are clay or silty clay. Reactions are neutral through moderately alkaline. Included with these soils in mapping are small areas of Stoneburg, or Lucien soils.

TABLE A-1. EXPLANATION OF SOIL NAMES

Formative Elements in Names of Great Groups and Suborders	Connotation
aqu	characteristics associated with wetness
fluv	associated with flood plains
ust	of hot climates, usually dry summers
hapl	minimum horizon
pale	old development
arg	an argillic horizon
ultic	ultimate in weathering
typic	typical, soils which typify the central concept of the Great Group
olls	Mollisols
alfs	Alfisols
ents	Entisols
psamm	sand textures
udic	of humid climates

(Continued)

TABLE A-1. (Continued)

arenic	soils which must have surface epipedons between 20 to 40 inches thick that have textures of loamy fine sand or coarser throughout
pachic	soils with a surface layer in excess of 20 inches that have characterisitcs of a mollic epipedon

Surface epipedons:

Mollic--A layer of soil more than 4 inches thick if underlain directly by a lithic contact or more than one-third the thickness of the solum if the solum is less than 30 inches, or more than 10 inches thick if the solum is greater than 30 inches. It must contain at least one percent organic matter and base saturation must be over 50 percent. For color of the mollic epipedon, the value must be darker than 3.5 when moist and 5.5 when dry, and chroma of less than 3.5 when moist. Structure is usually porous granular type.

Ochric-- Epipedons too light in color, too high in chroma, or too thin to be mollic or any other diagnostic surface horizon, or they are both massive and hard when dry.

Diagnostic subsurface horizons:

Argillic-- An illuvial horizon in which silicate clays have accumulated.

Cambic--A subsurface horizon which must have some evidence of pedongenic processes at work but not strongly enough to be an argillic or other subsurface horizon.

Lithic contact--A boundary between soil and a continuous, coherent underlying material with a hardness of 3 or more on the Mohs scale.

Paralithic contact--Differs from lithic in that the hardness of the underlying material is less than 3 on the Mohs scale.

Particle-size classes for Family groupings:

Coarse loamy--with less than 19 percent clay.

Loamy--More than 15 percent fine sand or coarser and between 0 and 35 percent clay.

Coarse loamy--Less than 18 percent clay but less than 35 percent clay and greater than 15 percent fine sand or coarser.

(Continued)

TABLE A-1. (Continued)

Fine-loamy--More than 18 percent clay but less than 35 percent clay and greater than 15 percent fine sand or coarser.

Fine-silty--with more than 18 percent clay but less than 35 percent clay and more than 15 percent fine sand or coarser.

TABLE A-2. PROPORTION OF SOIL TYPES ON WATERSHED

Soil Symbol	Soil Name	Approx. Acreage	% Extent
1	Aydelotte loam, 3 to 6 percent slopes[1]	9.5	7.0
2	Darnell fine sandy loam, 3 to 6 percent slopes	6.0	4.5
3	Darnell-Rock outcrop complex, 1 to 8 percent slopes[2]	2.0	1.5
4	Grainola loam, 0 to 3 percent slopes[3]	7.5	5.6
5	Grainola loam, 3 to 6 percent slopes[3]	16.0	11.7
6	Lucien sandy loam, 1 to 3 percent slopes[4]	3.5	2.6
7	Lucien loam, 3 to 5 percent slopes	12.0	9.0
8	Lucien loam, 5 to 8 percent slopes	3.5	2.6
9	Lucien-Rock outcrop complex, 8 to 30 percent slopes[4]	1.0	0.7
10	Renfrow loam, 3 to 5 percent slopes[5]	1.0	0.7
11	Stephenville sandy loam, 3 to 6 percent slopes	3.0	2.2
12	Stoneburg loam, 1 to 3 percent slopes[6]	2.0	1.5
13	Stoneburg loam, 3 to 6 percent slopes[6]	33.0	24.1
14	Stoneburg-Channel complex, 1 to 30 percent slopes[6]	27.0	20.0

(Continued)

TABLE A-2. (Continued)

Soil Symbol	Soil Name	Approx. Acreage	% Extent
15	Zaneis loam, 3 to 6 percent slopes7/	10.0	7.5
	Total	137.0	100.0

1/ These soils are typically outside the Aydelotte series range in that solum is 102 to 153 cm and the upper part is developed from sandstone. However, their response to use and management are similar to Aydellote soils.

2/ These soils are typically outside the Darnell series range in that the solum thickness is less than 25 cm. However, their use and management are similar to Darnell soils.

3/ These soils are typically outside the Grainola series range in that the A1 horizon is loam texture and developed in materials weathered from sandstone; and the upper solum reaction is more acid. However, their use and management are similar to Grainola soils.

4/ These soils are typically outside the Lucien series range in that the solum thickness is less than 25 cm, or they lack mollic epipedon. However, their use and management are similar to Lucien soils.

5/ These soils are typically outside the Renfrow series range in that the B3 horizon colors are 4 chroma. However, their use and management are similar to the Renfrow soils.

6/ These soils are typically outside the Stoneburg series range in that they lack mollic epipedons. However, their use and management are similar to the Stoneburg soils. Series name being changed to "Coyle".

7/ These soils are typically outside the Zaneis series range in that the lower subsoil is clayey. However, the agronomic and range use and management are similar to Zaneis soils. For engineering use and management refer to the Zaneis and Renfrow series.

APPENDIX B

DISCHARGE EQUATIONS AND RATING TABLES FOR THE MAIN RUNOOF MEASURING WEIR

Head Range (Ft)	Equation for Discharge in Cfs
0 to 0.08	$Q = \{3.0363 + 0.89276 \log H\}\{2.02674\} H^{2.5}$
0.09 to 0.23	$Q = \{2.2868 + 0.20316 \log H\}\{2.02674\} H^{2.5}$
0.24 to 1.00	$Q = \{2.5289 + 0.58982 \log H\}\{2.02674\} H^{2.5}$
1.00 to 2.17	$Q = \{2.673 + 0.38530 \log H\}\{2.0052 H + 1.33 \frac{V^2}{2g}\}^{2.5}$
2.18 to 5.50	$Q = \{2.772 + 0.09156 \log H\}\{2.0052 H + 1.33 \frac{V^2}{2g}\}^{2.5}$

APPENDIX C

SUMMARY OF WATER ANALYSES PROCEDURES

TOC

Samples were analyzed using a Beckman Model 915 Total Organic Carbon Analyzer equipped with a Model 215B Infrared Analyzer and a Beckman Ten-Inch Potentiometric Recorder. This system provides rapid analysis of a micro sample of aqueous solution for determination of either of two quantities:

1. Total carbon (organic carbon plus carbon in carbonates).
2. Inorganic (i.e., carbonate) carbon.

For the determination of total organic carbon, the two analyses were performed on successive identical samples; the desired quantity was the difference between the two values obtained. Both analyses were based on the conversion of sample carbon into carbon dioxide by catalytic combustion or wet chemical oxidation for measurement by the non-dispersive infrared analyses.

Sample handling, preservation and procedure for analysis were taken from EPA Manual of Methods for Chemical Analysis of Water and Wastes 1974, Organic Carbon (Total and Dissolved) on page 236.

SUSPENDED SOLIDS

Suspended solids were analyzed according to EPA Manual for Chemical Analysis of Water and Wastes 1974, Residue, Total Non-Filterable on page 268. A well mixed sample was filtered through a standard glass fiber filter, and the residue retained on the filters dried to constant weight at 103-105C.

CHEMICAL OXYGEN DEMAND

Summary of Method

Organic substances in the sample were oxidized by potassium dichromate in 50% sulfuric acid solution at reflux temperature. Silver sulfate was used as a catalyst and mercuric sulfate was added to remove chloride interference. The excess dichromate was titrated with standard ferrous ammonium sulfate, using orthophenanthroline ferrous complex as an indicator.

The procedure used for this determination is found in EPA Manual of Methods for Chemical Analysis of Water and Wastes 1974, Chemical Oxygen Demand, pages 20 and 21. Standard Methods for the Examination of Water and Wastewater, 14th edition, page 550 Method 508 (1976).

Quality Check

The technique and quality of reagents were checked several times by the technician analyzing agronomy samples from November 1978 until May 1979. EPA assurance samples were analyzed on September 19, 1978 and November 17, 1978. Values obtained were 228.5 mg/l and 12.8 mg/l; actual values were 231 and 15.4 mg/l, respectively. On October 24, 1978 a sample was sent to six laboratories within the state as a routine quality check. The average value was 70.7 mg/l with a standard deviation of ±4.1; our value obtained was 72.7 mg/l COD.

PHOSPHORUS

Summary of Method

Ammonium molybdate and antimony potassium tartrate react in an acid medium with dilute solutions of phosphorus to form an antimony-phosphomolybdate complex. This complex is reduced to an intensely blue-colored complex by ascorbic acid. The color is proportional to the phosphorus concentration.

Only orthophosphate forms a blue color in this test. Polyphosphates (and some organic phosphorus compounds) may be converted to the orthophosphate form by sulfuric-acid-hydrolysis. Organic phosphorus compounds may be converted to the orthophosphate form by persulfate digestion.

Total phosphorus, as analyzed, is defined as all of the phosphorus present in the sample, regardless of form, as measured by the persulfate digestion procedure. Dissolved phosphorus, as analyzed, is defined as all of the phosphorus present in the filtrate of a sample filtered through a phosphorus-free filter of 0.45 micron pore size and measured by the persulfate digestion procedure.

Procedure

The first set of samples dated November 15, 1978 were analyzed according to EPA Manual for Chemical Analysis of Water and Wastes 1974, page 249, Phosphorus, all forms (Single Reagent Method). The remainder of the samples were analyzed using Hach Procedures, Chemical Lists and Glassware for Water and Wastewater Analysis, 3rd edition, pages 2-104, Phosphate, Total, Organic and Inorganic. This method is based on APHA Standard Methods for Examination of Water and Wastewater, 13th edition, page 524 (1971). Samples were kept refrigerated at 4C and analyzed within 24 hours of reception.

POTASSIUM - Total

Procedures follows method used in Methods for Chemical Analysis of Water and Wastes (EPA-600/4-79-020) section 4.1.3 of the "Metals" unit. A 100 ml sample was taken within 24 hours of delivery and acidified with 3 ml concentrated HNO_3, placed in a 250 ml beaker on a warm hot plate and evaporated to near dryness. The beaker was cooled, 3 ml of concentrated HNO_3 added, and returned to hot plate with a watch glass atop the beaker and the sample digested for several days with more HNO_3 added as needed to prevent drying out of sample. The beaker was cooled then 3 ml of 1:1-HCL: H_2O added. Beaker was warmed. Sample was then brought to original volume with 0.2N HNO_3.

POTASSIUM - Suspended and Dissolved

A 50 ml sample was filtered with 0.45 gelman membrane, following the EPA method.

Dissolved Portion -

To 50 ml sample, 3 ml concentrated HNO_3 added and sample stored in poly bottle.

Suspended Portion -

Filter membrane placed in beaker, 3 ml concentrated HNO_3 added, then placed on hot plate, with a watch glass on top for reflux digestion for several days. Additional concentrated HNO_3 added as needed to prevent drying. Watch glass removed, sample evaporated to near dryness, cooled, 3 ml of 1:1-HCL:H_2O added. Sample is reheated then brought to original volume with 0.2N HNO_3.

All labware used was washed with the following method:

1. Soaked for 15 minutes in hot water and Micro Cleaning Solution.
2. Rinsed 3 times with tap water.
3. Rinsed 3 times with tap distilled water.
4. Rinsed 2 times with double distilled deionized water.
5. Rinsed 2 times with 0.2N HNO_3.
6. Air dried.

Analysis was done on Varian Techtron (Model AA-5) with prepared "Fisher" Brand Standards.

NITRATE, NITRITE, AMMONIA, AND PARTICULATE NITROGEN

Nitrate (NO_3^-), Nitrite (NO_2^-) and Ammonia (NH_4^+).

Surface runoff water was centrifuged for 1 hour at 8000 g. to sediment the suspended particles. Then 5, 10, or 25 ml of the supernatant was withdrawn and used in a micro application of the methods cited below. In each case a standard curve was prepared each time samples were run. Light path was 1 cm. A Beckman Spectrophotometer (model 24) was used in all cases (including the method described for PN).

Ammonia was analyzed on 5 ml samples following the spectrophotometric method of Solorazano (1969). This method involves the development of the blue color of indophenol by the reaction at high pH of ammonia, phenol and hypochlorite. Optical density of standard samples and runoff samples was read at 6400$\overset{\circ}{A}$.

Nitrate was analyzed on 25 ml samples using the method of Mullin and Riley (1955). This method involves the reduction of No_3^- to NO_2^- in the presence of a hydrazine-copper reagent for 24 hours and color development with 1-napthylamine. Optical density of standard samples and runoff samples was read at $5240\mathring{A}$.

Nitrite was analyzed on 5 ml samples using the method of Strickland and Parsons (1968). This colormetric determination involves reaction with sulfanilamide and color development with N - (1-napthyl) - ethylenediamine. Optical density of standard samples and runoff samples was read at $5430\mathring{A}$.

Particulate Matter (PM) and Particulate Nitrogen (PN)

Particulate matter and PN is defined here operationally as those materials retained by a Reeve Angel 984 H glass fiber filter (GFF). In determining PM, 50 ml was filtered through a preweighted and muffled (450C) GFF. The filter was dried to constant weight at 105C and reweighed. The concentration of PM per liter was caluclated as the difference between the filter weight before and after filtration and drying, multipled by twenty. The PM on the filter was analyzed for PN using the method of Holm-Hansen (1968). The filter was digested in a mixture of $Se\text{-}H_2SO_4$ (essentially a Kjeldahl digestion solution) for 2 hours at 250C in a test tube. After cooling, the contents of the tubes were made alkaline, cooled and centrifuged. The supernatant was drawn off, placed in another clean test tube and ninhydrin-hydrindant in mixture was used to complex with NH_4^+ and develop color. Optical densities were corrected for N remaining in the muffled filters by running blank filters.

APPENDIX D

DAILY METEOROLOGICAL AND RUNOFF DATA

TABLE D-1. DAILY METEOROLOGICAL AND RUNOFF DATA FOR APRIL, 1976

	Air Temp						Rainfall		
Date	Max °C	Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Gage 1 mm	Gage 2 mm	Runoff mm
1	22.2	8.3			225				
2	27.8	10.0			161				
3	21.1	5.5			185				
4	18.3	2.2			124				
5	22.2	6.7			119				
6	24.4	12.8			127				
7	23.3	13.9			92				
8	25.0	5.0			71				
9	22.2	9.4			151				
10	25.5	14.4			140				
11	25.5	10.5			183				
12	26.1	13.3			161		8.1	9.4	0.00
13	23.9	16.1			154				
14	26.7	15.5			196	1.8			
15	23.9	11.7			238	7.4	10.2	10.2	0.00
16	24.4	11.7			352	5.8			
17	20.5	10.5			367	9.1	8.9	8.9	0.00
18	23.3	10.0			134	2.0			
19	22.2	11.1			92	3.0	5.6	5.6	0.00
20	18.3	6.1			174		5.1	4.3	0.00
21	22.8	12.2			204				
22	27.2	13.3			233	7.9			
23	28.3	15.0			196	5.1			
24	22.8	11.7			201	6.6			
25	22.2	12.8			312	3.0			
26	18.9	11.7			209	2.5			
27	20.5	9.4			126	3.3			
28	12.8	8.9			243	3.0	20.3	19.6	0.00
29	16.7	10.0			161	2.3	3.8	3.8	0.00
30	15.5	6.7			85	4.1			
						TOTAL	62.0	61.8	0.00

TABLE D-2. DAILY METEOROLOGICAL AND RUNOFF DATA FOR MAY, 1976

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	19.4	11.1			127	11.2			
2	21.7	4.4			154	4.1			
3	17.2	6.1			140	3.6			
4	24.4	10.5			179	4.8			
5	13.3	10.0			145	2.3			
6	17.2	12.2			80	3.0			
7	20.0	11.1			39	1.8			
8	21.1	4.4			145	0.0			
9	25.0	10.0			143	3.3			
10	22.2	11.1			101		12.7	12.7	0.00
11	17.8	7.2			69	6.9			
12	18.3	8.3			114	3.0	27.9	25.4	0.99
13	20.5	8.3			153	6.1			
14	20.5	12.8			84	2.8			
15	17.8	14.4			220	4.1	2.5	2.5	0.00
16	21.1	11.7			237	5.8			
17	22.8	10.0			129	6.1			
18	23.3	13.3			106	7.6			
19	24.4	14.4			177	11.4			
20	24.4	16.7			183	5.8			
21	26.7	18.3			174	1.7			
22	26.7	15.5			130				
23	26.7	15.0			145	6.6	15.2	15.2	0.00
24	24.4	15.0			122	5.1			
25	23.3	15.0			143	1.0			
26	19.4	14.4			200	1.8	21.6	21.6	0.97
27	20.5	10.5			92	4.3			
28	26.7	14.4			87	6.4			
29	30.0	20.5			135	7.4			
30	29.4	17.8			122	3.8			
31	22.2	15.5			114	1.0			
					TOTAL		79.9	77.4	1.96

TABLE D-3. DAILY METEOROLOGICAL AND RUNOFF DATA FOR JUNE, 1976

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	22.2	15.5			40	7.6			
2	29.4	13.9			37	5.1			
3	30.5	15.5			37	3.0			
4	27.2	15.0			39	10.7			
5	27.8	18.3			72	8.1			
6	25.5	18.3			84	5.3			
7	26.1	18.9			55	10.9			
8	27.2	16.1			64	4.3			
9	28.9	15.5			142	15.0			
10	30.0	19.4			102	11.9			
11	31.1	21.1			199	14.0			
12	31.7	21.1			198	12.4			
13	32.2	22.8			210	6.6			
14	32.7	23.9			157	5.8			
15	30.0	15.5			82	10.9			
16	30.5	15.0			101	9.1			
17	32.2	15.5			159	8.9	3.8	2.5	0.00
18	32.2	18.3			89	9.9	5.1	6.4	0.00
19	25.0	12.8			97	6.6			
20	27.2	12.8			91	10.4			
21	30.0	17.8			93	6.9			
22	30.5	18.3			225	8.1			
23	29.4	23.9			148	15.0			
24	31.1	21.1			56	8.6			
25	29.4	16.1			82	9.4			
26	30.5	21.1			127	8.4			
27	32.2	23.3			166	7.4			
28	35.5	20.0			74	8.4	15.2	12.7	0.00
29	37.2	19.4			116	7.4			
30	35.0	20.5			110	12.7			
					TOTAL		24.1	21.6	0.00

TABLE D-4. DAILY METEOROLOGICAL AND RUNOFF DATA FOR JULY, 1976

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	36.7	18.3			172	9.7			
2	28.3	17.8			132	6.9			
3	27.2	21.1			169	8.4			
4	30.5	20.0			39	2.5			
5	26.7	17.8			132	5.1			
6	28.9	17.2			55	2.8			
7	31.7	14.4			130	4.8			
8	32.2	18.9			254	7.6			
9	35.0	18.3			106	10.2			
10	34.4	17.8			253	6.4			
11	33.3	17.8			146	8.9			
12	34.4	16.1			138	9.1			
13	32.2	21.1			103	7.4			
14	33.3	21.1			126	10.7			
15	32.2	21.7			145	0.8	37.1	39.4	0.00
16	31.7	18.3			132	9.4			
17	30.5	18.3			121	10.4			
18	31.1	18.3			100	8.4			
19	32.2	20.0			222	9.1			
20	33.3	22.2			134	7.9			
21	35.0	24.4			145	8.1			
22	35.5	24.4			145	9.7			
23	34.4	22.8			126	7.9			
24	35.0	22.8			134	7.6			
25	37.8	23.3			158	7.9	11.7	20.6	0.00
26	37.8	23.3			142	7.9			
27	38.3	26.7			79	7.6			
28	37.8	26.1			237	12.2	15.0	8.1	0.00
29	33.9	22.2			100	8.9			
30	36.1	23.3			137	7.6			
31	38.9	24.4			145	7.9			
						TOTAL	63.8	68.1	0.00

TABLE D-5. DAILY METEOROLOGICAL AND RUNOFF DATA FOR AUGUST, 1976

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	40.0	25.5			249	8.9			
2	38.9	24.4			127	7.6	32.3	34.8	0.00
3	26.1	16.1			122	8.4			
4	27.8	17.8			192	7.4			
5	30.5	20.5			18	7.9			
6	37.8	18.9			98	11.4			
7	34.4	24.4			447	6.4			
8	33.3	25.5			101	10.4			
9	38.9	23.3			204	12.4			
10	40.0	22.2			192	12.4			
11	40.0	23.9			129	8.1			
12	38.3	21.7			161	10.4	5.1	3.8	0.00
13	37.8	22.2			103	8.6			
14	38.3	21.7			196	8.1	3.6	3.6	0.00
15	37.8	21.7			100	7.4	1.5	1.3	0.00
16	36.7	21.7			122	10.4			
17	36.7	21.7			95	7.6			
18	35.5	21.1			111	10.2			
19	33.9	17.8			72	9.1			
20	33.3	15.5			58	6.6			
21	33.3	18.9			80	8.9			
22	33.3	18.3			109	10.4			
23	35.0	18.9			69	6.9			
24	35.0	15.0			55	8.1			
25	31.7	16.1			103	9.7			
26	35.0	21.1			82	7.9			
27	36.7	18.9			127	8.4			
28	38.3	20.0			97	9.1			
29	31.1	17.8			105	9.1			
30	34.4	16.7			80	4.6			
31	29.4	17.2				8.9	8.1	9.9	0.00
						TOTAL	50.6	53.4	0.00

TABLE D-6. DAILY METEOROLOGICAL AND RUNOFF DATA FOR SEPTEMBER, 1976

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	26.2	17.5	74		34	4.3			
2	28.5	15.5	72		45	4.6			
3	37.5	18.2	65		61	7.4			
4	36.0	20.9	59		48	7.6			
5	35.1	21.5	54		74	7.9			
6					56	7.1			
7					61	7.6			
8					163	6.1			
9					129	6.4			
10					143	6.1	4.8	5.3	0.00
11					116	7.1			
12					113	6.1			
13	26.0	19.5			103	5.8			
14	31.5	15.1	64		14	4.8			
15	31.5	10.2	74		76	5.3			
16	27.0	18.0	88		35	7.6	7.1	10.4	0.00
17	29.0	18.6	78		45	8.4	22.9	21.3	0.00
18	28.5	19.2	79	334	64	7.4			
19	27.0	20.2	77	291	58	11.2	1.5	10.2	0.00
20	22.5	14.0	70	313	87	7.1	1.5	1.5	0.00
21	26.2	9.5	56	499	63	7.1			
22	29.0	12.2	55	495	108	8.1			
23	28.5	18.0	59	470	111	6.4			
24	30.5	14.0	66	463	68	4.1			
25	25.0	19.0	74	115	97	3.8	39.4	39.6	0.00
26	20.2	15.2	90	113	146	1.8	1.0	1.3	0.00
27	17.0	12.3	79	127	208	3.6			
28	16.0	10.8	70	265	69	3.3			
29	21.0	7.5	60	466	34	4.6			
30	28.2	10.2	51	476	27	5.3			
						TOTAL	78.2	89.6	0.00

TABLE D-7. DAILY METEOROLOGICAL AND RUNOFF DATA FOR OCTOBER, 1976

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	33.5	12.0	52	464	23	0.20			
2	32.4	13.5	52	412	182	0.11			
3	28.7	16.5	61	303	51	0.12			
4	24.0	13.2	83	197	220	0.16			
5	16.5	8.2	78	325	87	0.20	0.5	0.5	0.00
6	12.2	6.0	79	122	166	0.00	9.9	8.6	0.00
7	11.0	7.2	66	103	158	0.07			
8	16.0	2.0	67	411	23	0.24			
9	22.0	7.0	62	433	80	0.05			
10	28.0	8.9	56	428	119	0.33			
11	29.5	12.2	54	432	108	0.33			
12	27.0	13.2	57	422	106	0.24			
13	25.5	10.2	62	402	90	0.29			
14	26.9	10.0	58	402	439	0.36			
15	18.0	9.9	54	319	224	0.20			
16	13.0	3.7	54	393	100	(1)			
17	13.0	-0.1	62	358	127				
18	14.2	5.4	72	125	116				
19	7.0	0.8	58	155	166		1.5	1.5	0.00
20	17.2	6.9	58	392	64				
21	21.5	1.5	55	380	153				
22	20.3	5.2	68	245	285				
23	22.0	16.0	87	224	198				
24	17.0	6.1	84	98	299				
25	10.5	2.6	76	186	140				
26	13.5	1.0	72	304	175				
27	11.2	4.0	75	167	174		0.8	0.5	0.00
28	12.1	0.7	67	317	61		0.5	0.8	0.00
29	8.0	4.2	93	32	119				
30	8.8	3.7	91	98	60		25.4	25.9	0.00
31	15.3	2.8	77	321	58		1.3	2.0	0.00
						TOTAL	39.9	39.8	0.00

NOTE:

1. Evaporation data not available after October 15 because pan was removed from service to prevent damage by freezing temperatures.

TABLE D-8. DAILY METEOROLOGICAL AND RUNOFF DATA FOR NOVEMBER, 1976

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	18.2	4.0	68	334	95				
2	22.1	6.0	63	330	76				
3	15.7	4.1	57	306	100				
4	7.8	-0.7	58	339	117				
5	15.2	-1.9	60	320	143				
6	23.0	4.7	63	317	212				
7	12.5	1.5	54	331	47				
8	15.5	1.5	53	314	153				
9	23.0	5.5	66	307	106				
10	17.0	4.0	51	306	124		10.2	10.2	0.00
11	8.3	-3.5	80	80	148				
12	2.0	-7.0	57	252	175				
13	2.0	-3.2	55	158	72				
14	1.0	-1.3	82	75	93				
15	2.0	-2.5	84	139	76				
16	1.0	-1.1	95	68	129				
17	17.0	-1.7	72	257	55				
18	22.0	4.0	51	291	87				
19	20.5	4.8	64	271	85				
20	15.1	2.1	51	276	280				
21	8.0	-1.7	60	291	63				
22	9.0	-5.1	56	280	109				
23	12.8	0.2	56	226	93				
24	19.9	0.0	67	277	138				
25	18.5	7.3	78	135	290				
26	17.0	1.0	71	242	352				
27	1.0	-9.0	60	212	436				
28	-2.0	-10.6	58	245	182				
29	3.0	-11.0	58	270	113				
30	10.3	-9.5	46	270	140				
						TOTAL	10.2	10.2	0.00

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TABLE D-9. DAILY METEOROLOGICAL AND RUNOFF DATA FOR DECEMBER, 1976

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	7.8	-6.0	67	101	111				
2	10.2	-6.0	67	263	71				
3	13.0	-2.7	67	256	164				
4	9.3	-2.0	72	235	137				
5	10.8	-1.2	86	99	174		2.5	4.1	0.00
6	6.9	-8.6	76	50	257		2.0	1.5	0.00
7	5.5	-11.5	59	220	127				
8	4.5	-8.0	62	254	185				
9	15.0	3.0	68	249	339				
10	12.0	-4.0	92	16	142				
11	0.0	-6.2	85	70	154				
12	12.1	-2.8	69	253	119				
13	8.5	-5.6	69	258	71				
14	13.5	-1.0	71	246	166				
15	12.0	-1.8	71	220	277				
16	19.0	-2.7	51	252	129				
17	20.5	1.0	43	248	113				
18	19.0	1.8	67	242	101				
19	13.0	0.0	72	211	66				
20	0.2	-5.0	54	260	129				
21	2.0	-12.0	60	254	132				
22	9.8	-2.2	54	244	140				
23	9.0	-4.4	59	251	179				
24	14.5	2.0	66	241	164				
25	7.9	-2.6	66	247	106				
26	18.4	-4.0	53	249	117				
27	16.5	5.0	40	233	174				
28	7.2	-0.5	64	252	346				
29	9.2	-5.0	57	253	124				
30	5.0	-14.0	73	154	132				
31	-6.0	-16.0	60	246					
						TOTAL	4.5	5.6	0.00

TABLE D-10. DAILY METEOROLOGICAL AND RUNOFF DATA FOR JANUARY, 1977

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	-2.6	-12.1	54	144	119				
2	-3.0	-5.2	92	45	148				
3	-3.9†	-4.2†	98†	48	246				
4	1.0†	-5.2†	77†	103					
5	-3.2	-7.0	82	81					
6	-0.2	-6.2	89	110	227				
7	11.2	-7.7	61	263	211				
8	2.9	-13.2	83	80	240		10.2	10.2	0.00
9			89	164	418				
10	-7.2†	-14.0†	65	288	84				
11	-1.7	-15.7	80	268	135				
12	0.0	-10.5	92	114	142				
13	1.2	0.0	99	42	100				
14	4.7	-1.3	83	254	119				
15	4.7	-10.0	88	152	132				
16	-5.3	-13.5	61	282	145				
17	10.0	-10.2	68	232	356				
18	-3.0	-14.3	66	290	180				
19	7.9	-9.0	65	238	158				
20	13.0	-8.0	56	286	71				
21	7.9	-2.7	70	276	72				
22	4.0	-4.1	87	99	130		3.3	3.3	0.00
23	2.9	-2.2	97	62	137		1.8	1.8	0.00
24	6.6	-3.0	74	308	117				
25	10.7	-5.0	61	307	113				
26	11.5	-4.1	61	304	122				
27	15.2	-3.8	58	306	114				
28	4.0	-11.2	59	310	153				
29	4.8	-11.9	48	287	90				
30	0.7	-8.2	57	241	142				
31	9.0	-10.8	61	316	270				
						TOTAL	15.3	15.3	0.00

†Indicates that continuous data were not available

TABLE D-11. DAILY METEOROLOGICAL AND RUNOFF DATA FOR FEBRUARY, 1977

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	8.7	-6.2	75	303	71				
2	6.9	4.0	82	66	142				
3	11.0	-0.8	72	281	121				
4	14.0	-1.1	61	309	114				
5	12.0	-6.2	56	339	117				
6	13.0	-3.8	62	282	119				
7	5.0	-9.0	73	310	126				
8	15.0	0.1	67	324	126				
9	18.5	2.0	68	336	166				
10	18.0	4.0	72	324	167				
11	9.1	6.2	100	37	156		22.4	22.6	0.00
12	14.0	5.0	70	355	134		1.3	1.3	0.00
13	20.3	1.0	60	363	179				
14	12.2	-1.0	70	336	212				
15	1.9	-4.2	73	262	72				
16	9.9	-5.1	82	246	56				
17	18.8	0.2	61	374	117				
18	19.3	0.0	55	372	130				
19	11.5	0.2	59	379	154				
20	16.4	-1.3	52	395	135				
21	23.9	2.4	52	380	230				
22	23.5	11.5	69	210	467				
23	13.8	8.0	62	107	499				
24	18.0	3.7	38	341	259				
25	11.2	6.0	55	206	191				
26	6.2	-1.9	93	129	122		6.6	5.1	0.00
27	9.2	-3.7	79	344	85				
28	14.9	-2.2	61	438					
						TOTAL	30.3	29.0	0.00

TABLE D-12. DAILY METEOROLOGICAL AND RUNOFF DATA FOR MARCH, 1977

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	11.2	-1.8	61	311	309				
2	11.4	8.3	77	40	307		2.0	2.0	0.00
3	10.6	2.0	54	376	201				
4	9.1	-1.3	65	438	105				
5	8.9	-3.2	68	293	113				
6	15.1	-0.2	54	447	88				
7	21.2	1.7	45	464	80				
8	24.6	8.5	35	407	327				
9	20.0	10.3	58	426	410				
10	18.8	9.9	83	302	401				
11	15.6	5.5	60	255	386				
12	10.3	3.0	70	147	351				
13	22.4	1.2	50	477	92				
14	26.5	7.1	56	483	322				
15	17.9	3.6	62	469	150				
16	16.2	4.1	48	403	145				
17	19.2	12.0	71	59	317		24.6	23.9	0.00
18	16.7	5.9	59	390	117				
19	15.0	6.0	52	498	253				
20	20.0	-0.5	54	489	269				
21	12.0	0.9	66	384	190				
22	17.9	-1.0	50	524	116				
23	21.5	4.0	45	518	111				
24	18.9	10.0	63	278	323				
25	17.8	10.6	88	185	171				
26	21.1	13.9	92	210	380		2.5	2.5	0.00
27	16.8	12.0	98	124	187		17.0	19.1	0.00
28	24.2	9.2	65	522	283		5.8	5.3	0.00
29	21.6	4.2	60	489	138				
30	16.2	5.1	47	566	148				
31	14.2	0.2	64	497	100				
						TOTAL	51.9	52.8	0.00

TABLE D-13. DAILY METEOROLOGICAL AND RUNOFF DATA FOR APRIL, 1977

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	15.0	8.0	89	143	230				
2	18.8	8.7	60	526	338				
3	20.2	5.8	73	352	193		2.8	2.5	0.00
4	14.9	3.1	70	464	280				
5	16.1	-0.7	58	542	140				
6	26.0	5.2	50	570	156				
7	28.5	11.1	45	570	117				
8	28.9	10.9	48	579	138	8.9			
9	27.1	12.8	52	578	261	13.2			
10	26.7	14.8	47	583	240	9.7			
11	24.2	14.1	58	451	267	8.4			
12	24.5	15.0	62	348	235	3.6			
13	25.1	15.0	79	228	159	4.3	1.5	1.8	0.00
14	23.6	12.9	63	428	103	5.1			
15	24.4	13.9	76	386	135		1.0	1.0	0.00
16	21.1	15.0	94	293	148	10.7	16.5	20.8	0.00
17	23.2	15.6	89	330	74	10.2	10.2	6.4	0.00
18	19.4	13.9	94	263	64	6.4	1.0	1.0	0.00
19	23.5	10.3	82	518	42				
20	27.0	13.0	92	275	98		13.5	12.7	0.00
21	13.0	10.1	98	132	42	0.8	2.0	1.5	0.00
22	16.0	8.8	94	246	90		0.5	1.0	0.00
23	19.3	10.0	87	374	77	5.8			
24	19.5	8.2	68	619	103	4.8			
25	19.0	5.0	63	572	61	4.8			
26	22.6	5.0	59	636	61	5.8			
27	28.6	12.2	58	580	262	10.2	1.0	1.5	0.00
28	28.9	18.0	69	572	140	6.1			
29	27.5	18.0	78	479	108	9.1			
30	23.0	16.9	93	343	98	4.8	2.3	2.0	0.00
						TOTAL	52.3	52.2	0.00

TABLE D-14. DAILY METEOROLOGICAL AND RUNOFF DATA FOR MAY, 1977

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	23.6	17.8	90	278	95	2.0	1.8	1.8	0.00
2	24.8	16.1	84	419	63				
3	28.7	15.0	78	572	156				
4	27.9	17.8	81	445	282	6.4	2.8	3.0	0.00
5	27.0	16.0	88	305	154		26.7	28.4	0.00
6	26.8	15.7	85	511	100	7.9			
7	29.2	17.9	81	577	71	7.1			
8	31.0	18.0	78	574	122	4.3			
9	25.7	16.0	79	526	103	6.4			
10	23.1	13.9	67	575	93	8.1			
11	23.0	10.7	61	575	134	7.4			
12	25.2	10.5	62	651	71	6.1			
13	26.0	13.0	84	361	203	7.4			
14	27.4	16.8	67	633	294	5.6			
15	30.0	17.8	74	622	203	5.8	1.8	0.00	0.00
16	28.0	15.2	78	398	261		19.3	17.8	0.00
17	25.8	15.0	81	497	301		7.6	8.9	0.00
18	26.2	19.3	74	548	163				
19	24.9	16.2	89	250	179		22.1	23.4	0.00
20	23.2	14.8	94	204	201		81.5	86.6	33.81
21	23.1	14.6	75	524	124		17.0	18.0	10.46
22	27.5	13.2	74	666	262	8.6			
23	26.6	15.3	88	467	135	5.8	37.6	39.4	13.26
24	28.2	18.3	78	601	119	6.9			.05
25	28.1	18.2	78	598	124	7.6			
26	28.0	19.0	80	423	122				
27	27.9	15.8	80	452	122	6.4	21.8	22.6	1.85
28	27.5	18.0	84	524	175	6.9			
29	28.3	18.3	84	406	76	5.6			
30	31.4	18.1	80	534	26		2.8	2.3	0.00
31	24.9	17.8	91	298	219		8.4	7.4	0.00
						TOTAL	251.2	259.6	59.43

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TABLE D-15. DAILY METEOROLOGICAL AND RUNOFF DATA FOR JUNE, 1977

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	29.4	16.5	70	683	97	6.6			
2	29.7	19.6	68	641	80	7.1			
3	33.0	18.8	72	583	80	7.9			
4	33.0	22.0	70	672	82	5.1			
5	34.9	21.6	63	672	114	7.4			
6	29.9	19.0	71	532	105	8.4	0.8	1.5	0.00
7	26.2	14.1	67	676	158	7.6			
8	30.3	15.4	61	662	140	7.9			
9	35.2	23.0	56	653	145	7.4			
10	32.9	24.2	66	636	113	7.9			
11	34.3	22.4	65	660	182	7.9			
12	33.4	21.4	79	449	190	7.9			
13	31.3	19.8	77		37	7.4			
14	33.0	20.6	70		108	7.4			
15	28.4	21.1	80		257	7.9			
16	29.0	21.0	85		130	7.9			
17	34.5	22.0	71		158	9.4			
18	34.1	23.5	70		177	7.9			
19	33.0	25.0	75		225	8.6			
20	34.3	21.7	67		153	11.2			
21	33.0	23.7	69		187	7.4			
22	32.7	21.0	76		159	6.9	5.8	5.8	0.00
23	31.1	21.8	81		214	5.1	2.0	2.3	0.00
24	27.0	20.3	90		163		2.5	2.0	0.00
25	28.7	24.1	83		87	0.8	15.2	15.2	0.00
26	28.9	21.9	87		42	5.3	3.0	0.8	0.00
27	34.0	22.1	83		275	7.1			
28	35.4	21.2	75		32	7.1			
29	32.2	20.8	79		237	7.9	0.5	0.3	0.00
30	34.1	21.1	71		196				
						TOTAL	29.8	27.9	0.00

TABLE D-16. DAILY METEOROLOGICAL AND RUNOFF DATA FOR JULY, 1977

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	27.5	18.0	88	373	140		45.7	45.7	2.49
2	32.3	22.7	75	615	245	14.0			
3	33.0	23.6	66	675	161	10.9			
4	32.9	21.8	64	679	200	11.4			
5	33.2	23.4	68	656	195	11.4			
6	34.0	22.9	66	669	129	10.4			
7	34.4	23.1	66	652	174	7.9			
8	29.2	21.1	83	478	106	1.3	8.4	8.9	0.05
9	31.3	22.3	84	502	114	8.6			
10	34.5	21.1	71	655	171	12.4			
11	35.3	25.9	57	646	262	14.2			
12	36.2	25.6	57	619	187	10.7			
13	35.6	23.8	53	670	158	11.4			
14	36.1	23.5	54	653	158	15.0			
15	35.7	24.0	70	501	122	8.1	5.3	3.3	0.03
16	36.0	24.4	64	634	188	14.7			
17	35.0	23.2	65	614	114	6.4			
18	35.0	23.4	58	644	156	14.0			
19	35.2	23.8	60	577	176	10.4			
20	36.9	23.0	66	643	142	8.4			
21	35.7	17.6	83	436	87		12.7	12.4	0.08
22	33.8	21.7	84	486	77				
23	37.2	22.1	70	631	114	11.7			
24	38.4	25.0	58	580	402	8.4			
25	40.0	26.1	57	627		10.7			
26	29.0	21.0	90	245	171	5.6			
27	28.3	18.8	87	351	85	7.1			
28	33.0	20.8	75	581	74	3.8			
29	35.6	21.2	60	639	114	8.4			
30	37.0	23.2	64	640			0.5	0.5	0.00
31	34.0	18.9	78	453			27.9	25.4	0.10
						TOTAL	100.5	96.2	2.75

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TABLE D-17. DAILY METEOROLOGICAL AND RUNOFF DATA FOR AUGUST, 1977

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	32.0	19.3	60	619	101	0.5			
2	33.9	18.9	65	622	56	5.1	1.8	2.8	0.00
3	32.9	21.2	69	530	143	7.6			
4	34.0	23.8	62	500	216	7.9			
5	34.9	24.0	64	559	193	10.7			
6	35.0	24.0	71	439	142	9.1			
7	36.2	24.8	62	606	185	10.4			
8	35.9	25.1	58	596	156	8.4			
9	36.7	25.1	59	577	174	9.4			
10	37.0	24.8	65	539	106	7.6			
11	26.6	20.0	90	276	177	5.3			
12	30.2	18.7	83	407	126	9.7			
13	25.9	20.0	97	172	58		22.4	23.4	0.00
14	34.1	21.1	85	485	109	5.3			
15	33.0	21.2	77	589	145	9.7			
16	37.0	23.6	74	458	109	2.0	3.6	4.1	0.00
17	25.2	20.0	96	158	82	4.6	10.7	8.1	0.00
18	26.0	16.7	75	330	134	3.8			
19	22.9	20.0	94	86	95		3.3	3.0	0.00
20	27.9	20.2	86	348	35	5.1			
21	31.2	20.2	81	482	43	4.6			
22	32.0	19.2	74	497	111	8.6			
23	34.2	20.9	82	484	79	6.4			
24	33.0	22.1	83	542	134	7.9			
25	34.9	22.1	71	539	254	8.4			
26	35.3	24.9	63	537	336	18.3			
27	33.4	25.2	68	540	402	2.0			
28	26.8	16.1	98	160	79		12.4	11.4	0.00
29	27.0	18.1	93	283	53	2.5			
30	31.0	21.1	78	484	106	5.6			
31	32.1	22.8	75	502	117	6.1			
						TOTAL	54.2	52.8	0.00

TABLE D-18. DAILY METEOROLOGICAL AND RUNOFF DATA FOR SEPTEMBER, 1977

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	31.9	22.5	74	500	84	5.6			
2	33.1	21.0	70	542	77	9.7			
3	33.9	21.3	66	486	34	1.5			
4	31.3	20.6	88	181	88		10.9	8.9	0.00
5	26.2	20.2	93	257	77	3.0	4.1	4.6	0.00
6	29.2	20.0	86	394	76	4.6			
7	29.1	19.8	84	472	79	5.6			
8	31.0	20.1	79	472	121	6.9			
9	26.7	17.0	79	345	150	8.4			
10	26.1	17.1	76	360	179				
11	25.9	18.8	93	242	167	0.5	14.7	15.5	0.00
12	32.5	21.2	75	448	204	0.8			
13	22.1	16.9	93	185	217	3.3	7.4	7.1	0.00
14	17.7	14.5	100	96	161		5.3	4.1	0.00
15	25.1	14.2	83	436	121		4.6	5.6	0.00
16	30.2	18.2	78	377	225	5.3*	3.8	3.8	0.00
17	31.1	21.8	76	388	156	6.4			
18	31.9	19.6	69	499	150	6.4			
19	25.1	14.8	74	504	72	4.8			
20	28.6	13.3	71	364	201	8.1			
21	33.3	21.7	67	465	212	7.6			
22	32.2	20.0	75	452	187	4.6			
23	28.4	21.1	82	154	88	5.3			
24	28.2	17.0	62	479	105	5.8			
25	31.8	18.0	72	468	106	5.6			
26	34.8	17.0	75	446	135	5.8	3.0	3.6	0.00
27	30.0	21.2	87	344	137	3.8	3.8	3.3	0.00
28	24.4	20.0	99	113	166	0.8			
29	28.5	19.6	92	358	182	10.9			
30	35.0	21.1	63	360	137	4.6			
						TOTAL	57.6	56.5	0.00

TABLE D-19. DAILY METEOROLOGICAL AND RUNOFF DATA FOR OCTOBER, 1977

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	28.2	15.3	69	301	90	4.6			
2	20.5	11.0	74	422	117	4.6			
3	20.1	7.9	68	434	100	1.3			
4	18.0	11.0	77	160	174	2.5			
5	22.2	13.2	75	221	124	3.5			
6	18.0	15.0	95	70	159	3.0	0.8	0.5	0.00
7	25.3	16.0	78	199	237	4.1	0.8	0.5	0.00
8	19.8	7.7	63	255	68	3.0			
9	22.3	4.4	60	368	154	2.8			
10	24.1	7.6	61	306	185	5.3			
11	15.3	5.0	60	421	209	3.3			
12	18.5	0.7	57	415	43	4.1			
13	26.8	5.2	42	407	69	7.6			
14	28.1	7.8	40	412	143	5.1			
15	17.7	5.0	58	349	80				
16	21.0	1.0	59	400	130				
17	29.8	9.8	52	385	92				
18	27.0	5.9	59	385	16				
19	25.1	7.0	60	377	27				
20	30.0	10.8	61	362	198				
21	28.9	14.3	72	333	200		5.6	7.6	0.00
22	25.2	15.9	91	198	84		23.1	22.9	0.00
23	15.9	12.0	100	63	72				
24	22.5	11.0	88	294	37				
25	19.1	12.0	90	246	109				
26	30.0	8.2	68	355	60				
27	28.7	15.0	66	281	117				
28	22.0	16.8	94	132	24		0.3	0.3	0.00
29	25.2	13.5	80	279	214				
30	20.9	18.1	94	56	111		5.6	6.6	0.00
31	25.6	17.8	84	305	34				
						TOTAL	36.2	38.4	0.00

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TABLE D-20. DAILY METEOROLOGICAL AND RUNOFF DATA FOR NOVEMBER, 1977

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	18.7	7.0	99	83	286		2.3	2.0	0.00
2	11.0	7.2	100	56	164		0.5	0.5	0.00
3	18.3	10.8	96	149	130				
4	20.8	12.5	81	303	105				
5	15.8	14.0	100	43	42				
6	16.3	13.5	98	68	58				
7	18.1	11.2	98	125	135				
8	14.0	4.0	100	38	4		26.2	26.5	0.00
9	7.8	0.0	67	237	373		4.6	4.6	0.00
10	12.6	-2.2	60	323	72				
11	17.7	2.0	71	307	42				
12	19.5	3.0	61	291	204				
13	20.8	9.0	70	280	138				
14	22.0	8.4	82	235	246				
15	20.2	10.0	89	169	74				
16	20.9	5.8	74	290	85				
17	15.0	2.8	61	294	51				
18	18.1	2.9	56	254	341				
19	22.1	15.0	88	169	344				
20	22.0	0.8	66	242	346				
21	6.8	-2.0	59	262	113				
22	12.6	-1.0	76	262	204				
23	12.0	3.0	91	119	106				
24	10.2	-1.0	87	182	126				
25	11.1	-1.0	64	252	148				
26	13.9	-3.1	56	235	121				
27	11.1	4.0	62	248	153				
28	5.0	2.5	77	23	126		0.5	0.5	0.00
29	10.7	-0.6	79	217	56				
30	8.8	-2.0	89	114	122				0.00
						TOTAL	34.1	34.1	0.00

TABLE D-21. DAILY METEOROLOGICAL AND RUNOFF DATA FOR DECEMBER, 1977

Date	Air Temp		Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall		Runoff mm
	Max °C	Min °C					Gage 1 mm	Gage 2 mm	
1	12.2	-1.6	67	259	85				
2	14.0	2.0	64	180	111				
3	20.1	2.1	63	208	80				
4	8.8	5.0	96	53	105		2.0	2.8	0.00
5	7.0	-7.0	86	92	275		2.8	2.5	0.00
6	-1.0	-9.7	54	260	172				
7	8.0	-6.0	64	233	274				
8	10.5	-9.0	77	97	338				
9	-4.8	-12.0	52	263	92				
10	3.5	-10.3	53	159	201				
11	7.1	-2.0	50	43	294				
12	15.0	6.8	95	21	246				
13	14.0	2.9	70	228	140				
14	17.0	-0.8	59	205	171				
15	20.8	6.6	47	238	293				
16	22.0	7.8	64	206	352				
17	13.0	2.8	51	224	109				
18	17.3	-1.0	52	217	150				
19	7.0	2.0	75	230	204				
20	5.0	-5.4	69	235	230				
21	3.9	-5.0	57	254	256				
22	14.0	-4.0	34	254	185				
23	18.8	2.0	39	233	166				
24	17.5	-3.0	57	241	140				
25	3.7	-6.4	66	248	151				
26	9.0	-5.5	62	237	243				
27	1.0	-8.0	75	200					
28	11.0	-3.9	64	232					
29	5.2	2.2	100	32			2.0	2.0	0.00
30	5.1	3.7	100	34	183				
31	5.5	-6.5	97	33	237				
						TOTAL	6.8	7.3	0.00

TABLE D-22. DAILY METEOROLOGICAL AND RUNOFF DATA FOR JANUARY, 1978

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	-5.9	-9.4	72	143.4	142				
2	6.0	-11.8	60	303.8	84				
3	8.2	-6.0	74	248.4	183				
4	12.6	-1.0	79	261.1	203				
5	9.4	-0.9	86	250.7	51				
6	14.7	-4.9	77	271.7	85				
7	8.3	-0.5	89	158.8	375				
8	-0.5	-9.3	54	297.9	277				
9	-5.9	-11.4	47	187.7	127				
10	-5.8	-11.0	53	215.2	156				
11	-4.2	-6.3	80	53.6	98		1.0	1.0	0.00
12	-1.7	-6.2	96	140.8	37				
13	4.0	-10.0	82	286.2	208		1.5	1.8	0.00
14	0.8	-10.0	73	297.7	24				
15	1.5	-4.9	82	163.6	230		5.3	3.6	0.00
16	4.4	-2.8		90.0	66		12.7	12.4	0.00
17	-2.8	-17.8		254.3	31				
18	-8.9	-16.7		137.0	164				
19	-7.0	-11.6	94	148.3	222				
20	-8.2	-10.4	93	278.3	74				
21	-5.0	-9.5	89	164.4	134				
22	1.0	-7.8	98	195.2	200				
23	0.9	-4.4	100	96.7	180		0.3	0.5	0.00
24	0.4	-1.2	100	61.9	217		0.5	0.3	0.00
25	0.0	-8.4	82	301.0	278		1.0	0.5	0.00
26	-2.1	-10.9	70	344.2	98		1.8	1.5	0.00
27	-3.5	-9.1	76	224.1	45				
28	2.0	-10.0	82	302.3	92				
29	-1.3	-10.3	73	307.4	150				
30	0.0	-4.0	88	103.9	111				
31	-2.8	-6.2	95	95.3	121		2.0	1.5	0.00
						TOTAL	26.1	23.1	0.00

TABLE D-23. DAILY METEOROLOGICAL AND RUNOFF DATA FOR FEBRUARY, 1978

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	1.1	-6.6	99	97.3	206		1.5	1.5	0.00
2	-5.0	-11.3	85	197.7	92				
3	3.8	-5.9	90	189.2	111				
4	1.9	-1.9	99	148.9	129				
5	0.0	-5.4	77	335.8	171				
6	1.7	-8.4	68	195.0	251				
7	-2.8	-7.1	100	106.6	216		3.3	2.3	0.00
8	-3.6	-6.8	88	149.6	222		1.3	1.0	0.00
9	-3.1	-6.7	94	201.9	109		1.5	1.8	0.00
10	0.2	-4.3	92	222.8	148				
11	1.0	-2.1	100	88.4	106		1.3	1.0	0.00
12	2.3	0.1	100	37.3	290		48.0	47.2	3.40
13	5.0	-5.6	93	201.1	201		2.8	2.3	0.00
14	-2.4	-8.9	92	352.1	130				
15	-1.1	-5.8	93	249.2	72		1.3	1.5	0.00
16	-2.1	-8.6	98	168.6	191		1.5	1.3	0.00
17	-5.8	-7.8	95	211.1	142		0.5	0.5	0.00
18	-7.2	-21.1	85	447.3	64				
19	1.8	-17.8	88	455.0	51				
20	3.3	-7.2	91	313.7	381				
21	-2.0	-11.8	75	468.6	84				
22	8.7	-6.5	73		187				
23	9.9	-0.7	67		105				
24	17.1	2.2	67	448.7	171				
25	2.8	-1.0	75	451.5	135				
26	7.9	-4.2	64	404.7	259		1.8	1.5	0.00
27	6.7	1.2	80	57.2	219				
28	3.1	0.4	99	76.6	212				
						TOTAL	64.8	61.9	3.40

TABLE D-24. DAILY METEOROLOGICAL AND RUNOFF DATA FOR MARCH, 1978

Date	Air Temp		Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall		Runoff mm
	Max °C	Min °C					Gage 1 mm	Gage 2 mm	
1	2.3	-0.2	100	62.6	201		0.8	0.8	0.00
2	4.0	-5.7	93	57.0	414		1.0	1.0	0.00
3	-3.1	-9.5	69	276.1	249				
4	0.0	-11.7	61	502.3	190				
5	12.6	-4.9	50	445.6	193				
6	19.8	3.9	72	248.7	217				
7	3.9	-0.3	100	42.4	354		2.5	2.5	0.00
8	5.0	-2.1	88	302.5	164				
9	12.0	-5.6	58	527.9	43				
10	19.2	1.0	52	447.6	357				
11	13.1	0.9	90	139.2	243				
12	15.9	-1.7	69	527.4	214				
13	20.0	5.8	77	356.3	74				
14	11.7	1.4	78	420.5	304				
15	8.9	1.6	93	193.9	121		3.0	5.6	0.00
16	11.2	8.2	65	516.2	153				
17	18.5	-0.3	54	506.9	113				
18	27.9	4.7	38	531.4	130				
19	23.1	12.8	56	516.4	404				
20	21.9	9.1	80	264.8	230				
21	22.0	4.0	59	554.1	84				
22	26.8	11.3	57	486.9	368		2.5	2.3	0.00
23	18.0	4.5	100	54.2	319		14.7	15.5	0.00
24	4.5	1.0	99	115.8	288		11.2	10.2	0.18
25	10.0	0.1	79	496.8	103				
26	14.2	-1.2	62	584.7	134				
27	23.5	2.4	53	582.4	56				
28	27.0	9.0	50	572.9	124				
29	26.4	12.1	59	515.7	106				
30	25.9	8.8	60	579.2	163				
31	27.9	14.0	55	485.8	265				
						TOTAL	35.7	37.9	0.18

TABLE D-25. DAILY METEOROLOGICAL AND RUNOFF DATA FOR APRIL, 1978

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	28.8	12.8		476	311				
2	29.4	16.7		318	299				
3	28.8	16.1		254	121		2.8	4.3	0.00
4	24.4	11.1		492	230		0.5	0.0	0.00
5	26.1	15.6	89.8	199	275		4.6	3.8	0.00
6	22.2	11.7	58.6	530	135				
7	27.2	14.4	76.4	586	265				
8	27.8	17.8	75.1	464	261				
9	28.3	18.3	91.8	243	381		8.4	9.4	0.00
10	25.0	10.6		218	71		5.6	5.6	0.00
11	14.4	1.7		655	143				
12	19.4	5.0		646	114				
13	25.0	5.6		623	222				
14	23.9	11.7		269	209				
15	27.8	14.4			249		1.8	1.8	0.00
16	27.8	15.6	94.8		206				
17	22.2	16.7	81.4		275				
18	27.8	7.2	50.8		385				
19	22.2	7.2	69.8		224				
20	16.7	0.0	73.2		126				
21	15.0	2.2	62.2		298				
22	20.0	7.8	55.2		122				
23	25.6	2.2	44.6		108				
24	25.6	7.8	49.3		179				
25	24.4	3.3	73.2		124				
26	19.4	4.4	62.3		171				
27	22.8	3.9	51.7		175				
28	26.7	11.1	76.5		307				
29	26.7	15.0	88.1		145		13.0	13.0	0.00
30	26.1	17.2	99.2						
						TOTAL	36.7	37.9	0.00

TABLE D-26. DAILY METEOROLOGICAL AND RUNOFF DATA FOR MAY, 1978

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	22.2	11.1			175	3.8	0.8	0.0	0.00
2	19.4	7.2			228	5.8	18.0	19.1	0.00
3	13.3	6.7			195	5.6	5.1	5.8	0.00
4	8.9	5.5			129	0.0			
5	15.0	7.2			116	2.3			
6	16.7	10.5			196	0.0			
7	21.7	8.9			148	0.5	4.3	4.3	0.00
8	23.0	10.0			116	5.3			
9	22.0	9.5	59		119	7.4			
10	24.5	12.0	70	495	154	8.1			
11	30.5	17.0	73	639	146	7.1			
12	24.0	18.0	66	664	212	5.8			
13	23.0	11.7	57	702	265	11.9			
14	31.3	10.8	62	703	151	7.1			
15	26.5	15.8	62	688	103	5.8			
16	24.0	11.0	76	671	166	5.3			
17	22.0	14.8	88	454	230	6.4			
18	26.0	16.0	97	289	262	6.9	3.6	4.3	0.00
19	31.0	18.8	78	456	277	3.8	4.8	5.3	0.00
20	25.0	17.9	92		105	7.4	14.7	11.4	0.00
21	22.0	16.8	99		80	1.3	11.7	8.4	0.00
22	29.0	19.0	84		150	5.3			
23	30.3	20.5	82	677	154	7.9			
24	29.5	20.0	78	620	211	7.1			
25	30.0	20.2	81	605	172	10.4			
26	28.1	17.7	83	444	190	6.4	4.8	5.3	0.00
27	22.0	16.0	99		130	8.4	49.3	49.0	0.91
28	25.6	16.0	95		72	2.5	4.6	4.3	1.57
29	27.0	16.0	80		137	4.6			
30	30.5	17.5	78		92	11.2			
31	30.5	21.0	77	672	208	9.9			
						TOTAL	121.7	117.2	2.48

TABLE D-27. DAILY METEOROLOGICAL AND RUNOFF DATA FOR JUNE, 1978

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	26.1	18.0	92	357	166	8.6			
2	21.0	16.8	95	229	129	3.8			
3	24.2	14.1	90	552	138	4.6			
4	27.5	16.0	89	460	114	7.9	0.5	0.8	0.00
5	24.0	17.0	93	372	121	2.5	40.1	45.7	5.82
6	25.0	17.0	86	401	66	3.6	7.1	7.9	0.13
7	30.0	17.8	75	683	64	7.6			
8	24.0	14.0	69	634	76	3.6			
9	28.0	14.0	68	640	92	5.3			
10	28.9	17.0	71	724	158	8.6			
11	32.0	22.0	71	675	227	8.6			
12	29.0	21.0	61	716	201	8.4			
13	27.5	17.0	71	649	63	6.9			
14	30.0	18.8	76	693	323	7.1			
15	32.5	21.5	74	689	233	8.6			
16	32.5	23.0	74	698	201	8.1			
17	33.0	24.2	76	698	237	8.1	3.0	4.3	0.00
18	25.0	17.0	99	162	129	0.8	21.3	18.0	0.08
19	31.0	18.0	79	670	196	6.1			
20	29.0	18.5	92	495	127	9.7	0.8	0.8	0.00
21	22.0	18.0	100	68	130	3.8	29.2	29.2	0.20
22	30.3	17.5	88	535	158	6.1	1.0	1.0	0.00
23	32.1	23.0	74	714		5.1			
24	33.1	24.2	76	609		13.7			
25	33.0	25.8	68	686		8.9			
26	33.0	24.0	67	713		7.6			
27	32.0	24.0	74	526		8.1			
28	33.3	23.2	76			9.9			
29	34.0	22.5	72		127	11.7			
30	34.0	24.0	70	625	98	11.7			
						TOTAL	103.0	107.7	6.23

TABLE D-28. DAILY METEOROLOGICAL AND RUNOFF DATA FOR JULY, 1978

Date	Air Temp		Rel Humid	Solar Radiation	Wind Travel	Pan Evap	Rainfall		Runoff
	Max °C	Min °C	%	Cal/cm^2	km	mm	Gage 1 mm	Gage 2 mm	mm
1	36.0	23.8	66	668	156	13.0			
2	36.0	22.0	67	701	182	12.2			
3	37.0	23.3	67	716	37	7.4			
4	36.0	23.5	67		84	7.6			
5	36.2	25.0	63		132	10.2			
6	36.0	25.4	68		175	13.0			
7	36.7	23.0	73		196	10.9			
8	38.0	23.8	64		90	8.4			
9	40.0	26.6	47		187	11.4			
10	38.0	23.8	61		117	11.9			
11	38.0	23.2	63		58	10.4	1.0	1.3	0.00
12	36.5	25.2	62		182	10.4			
13	38.8	26.0	64		203	9.9	5.6	3.8	0.00
14	38.0	20.0	69		183	15.0	0.8	0.0	0.00
15	34.5	22.0	75		156	11.4	1.3	0.0	0.00
16	34.6	22.0	68		90	9.1	1.3	3.8	0.00
17	35.1	23.0	63		97	9.4			
18	37.0	26.0	53		198	11.2			
19	37.2	25.3	57		264	10.4			
20	38.8	24.0	58		164	11.7			
21	37.2	23.9			161	5.1			
22	36.7	22.8			114	17.0	6.4	0.0	0.00
23	33.9	20.0			249	4.8	20.1	29.0	0.00
24	31.8	17.2			69	7.6			
25	35.2	22.0	66	650	60	6.4			
26	38.0	24.0	69	446	142	8.1			
27	32.7	18.8	58	672	100	9.4			
28	35.0	18.8	57	705	109	10.2			
29	38.0	24.7	53	683	116	0.0			
30	34.0	29.0	61	641	150	10.2			
31	35.0	19.2	68	651	182	0.0			
						TOTAL	36.5	37.9	0.00

TABLE D-29. DAILY METEOROLOGICAL AND RUNOFF DATA FOR AUGUST, 1978

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	32.0	21.0	69	632	212	11.4			
2	32.0	22.2	82	391	245	4.8	5.1	5.1	0.00
3	27.8	19.8	96	298	124	3.8	25.4	21.6	0.00
4	20.0	17.0	100	117	175	3.0	1.3	1.3	0.00
5	27.5	17.0	85	466	126	2.0			
6	31.0	17.0	70	661	53	6.6			
7	31.2	20.5	63	571	56	7.9			
8	32.0	19.5	51	603	80	8.9			
9	32.0	20.5	60	497	93	5.6			
10	31.2	20.5	69	409	40	5.6	11.9	13.2	0.00
11	36.5	21.8	60	638	48	2.5			
12	37.2	24.0	56	647	190	16.0			
13	38.0	25.0	58	631	191	19.8			
14	36.2	24.0	62	617	145	13.7			
15	34.6	26.0	64	493	291	11.2			
16	37.0	21.0	47	630	85	13.2			
17	37.8	20.0		621	175	15.2			
18	38.9	27.8		601	367	18.8			
19	38.9	16.7		192	285	6.1	15.0	16.5	0.00
20	32.8	13.9		606	92	3.8			
21	35.0	15.6		579	35	10.9			
22	34.2	23.0	62	573	135	9.1			
23	36.0	22.5	57		138	11.2			
24	36.0	24.0	56		195	11.4			
25	37.0	23.8	57		161	10.9			
26	36.2	25.2	62		191	10.9			
27	37.0	25.0	66		253	10.7			
28	27.0	19.8	83		265	8.9			
29	28.8	19.5	68		146	6.6			
30	27.5	15.0	61		209	8.1			
31	31.2	14.5	60		114	9.4			
						TOTAL	58.7	57.7	0.00

TABLE D-30. DAILY METEOROLOGICAL AND RUNOFF DATA FOR SEPTEMBER, 1978

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	31.1	20.0	70		129	5.8			
2	34.2	20.9	69		45	10.9			
3	36.8	22.9	59		142	8.9			
4	38.1	22.0	48		142	9.1			
5	29.0	21.9	62		74	7.1	0.8	0.8	0.00
6	35.8	20.0	56		48	3.0			
7	34.1	22.0	58		84	8.4			
8	31.4	20.6	67		84	10.2			
9	28.3	21.8	84		84	6.9			
10	32.9	20.7	78		129	4.8			
11	30.0	22.6	85		187	5.3			
12	36.2	23.4	80		293	6.6			
13	33.7	23.5	78		180	7.1	15.0	16.5	0.00
14	31.2	18.0	85		272	7.1			
15	35.8	22.6	72		200	7.1			
16	37.0	23.3	58		206	9.4			
17	33.5	25.2	67		175	6.4			
18	33.4	25.3	66		439	17.3			
19	33.2	24.0	68		333	12.7			
20	26.2	13.5	89		233	7.6	11.7	11.2	0.00
21	21.5	11.6	73		227	6.6	4.3	4.3	0.00
22	22.8	11.5	65		217	5.8			
23	28.4	12.7	75		72	4.6			
24	29.3	17.8	80		14	3.8			
25	24.0	19.9	84		58	1.5			
26	26.3	17.6	69		45	2.5			
27	29.7	15.0	74		92	2.5			
28	30.8	14.1	67		56	4.8			
29	31.0	16.9	62		45	4.1			
30	25.4	14.7	62		206	10.4			
						TOTAL	31.8	32.8	0.00

TABLE D-31. DAILY METEOROLOGICAL AND RUNOFF DATA FOR OCTOBER, 1978

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm2	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	29.8	11.9	60		219	7.1			
2	33.0	18.6	51		208	6.1			
3	24.9	14.4	50		422	9.1			
4	28.2	9.8	49		119	9.1			
5	23.0	10.0	48		309	7.1			
6	20.8	5.1	61	471	233	6.9			
7	26.2	7.7	57	459	116	7.1			
8	17.1	12.4	79	40	180	4.8	51.8	52.8	0.00
9	24.4	12.1	81	370	243	3.8			
10	27.8	15.6	70	439	154	3.8			
11	29.8	14.4	76	433	166	10.9			
12	32.0	16.5	66	431	140	2.0			
13	18.0	7.1	54	446	436	11.2			
14	21.0	3.9	56	446	224	7.9			
15	26.4	3.8	53	437	148	4.6			
16	23.0	6.9	57	436	138	5.3			
17	22.4	6.7	58	423	154	7.9			
18	27.1	10.0	54	415	270	4.8			
19	24.0	8.8	63	410	183	6.1			
20	29.9	9.2	59	401	51	5.6			
21	30.1	14.0	40	392	134	5.6			
22	25.6	8.8	82	252	447	8.6	2.5	2.8	0.00
23	12.8	7.0	66	234	414	5.8	3.6	3.6	0.00
24	20.3	3.7	78	296	148	2.8			
25	21.9	7.4	74	372	254	3.3			
26	17.4	3.6	67	403	180	1.3			
27	23.6	4.7	55	399	270	2.0			
28	24.1	6.2	52	389	93	6.4			
29	23.0	6.5	55	377	182	4.8			
30	26.0	7.6	59	367	126	4.3			
31	25.8	8.9	68	371	138	3.6			
						TOTAL	57.9	59.2	0.00

TABLE D-32. DAILY METEOROLOGICAL AND RUNOFF DATA FOR NOVEMBER, 1978

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	21.7	5.9	76	334	97				
2	26.8	8.7	63	365	63				
3	27.8	14.9	55	321	134				
4	26.7	13.6	68	282	163				
5	24.9	12.8	76	238	201		3.0	4.1	0.00
6	7.5	5.1	96	69	259		18.5	16.5	0.00
7	14.4	-0.3	70	358	220				
8	19.7	3.8	57	372	37				
9	20.8	7.3	60	340	248				
10	23.7	10.1	73	319	204				
11	10.4	4.1	91	194	212				
12	15.0	3.8	100	64	357		2.5	2.8	0.00
13	17.6	11.0	88	98	327		0.8	1.8	0.00
14	11.0	1.0	78	49	219		47.0	48.3	1.52
15	2.8	1.0	100	38	420		4.8	6.9	0.00
16	3.6	2.2	100	48	274		5.3	4.6	0.00
17	6.5	0.0	99	119	249				
18	17.9	0.1	85	303	84				
91	11.3	1.7	92	247	224				
20	5.0	0.0	94	115	134				
21	3.0	-1.0	97	105	338				
22	11.4	2.0	100	42	151				
23	16.0	8.6	83	232	122		3.0	3.6	0.00
24	15.5	3.0	78	218	219				
25	17.5	9.0	100	28	187		2.3	3.6	0.00
26	17.8	1.5	100	53	161		2.8	2.0	0.00
27	6.8	0.0	84	285	434				
28	11.5	-1.5	76	301	31				
29	13.0	4.0	78	292	64				
30	12.3	3.8	83	125	108				
						TOTAL	90.0	94.7	1.52

TABLE D-33. DAILY METEOROLOGICAL AND RUNOFF DATA FOR DECEMBER, 1978

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	14.1	5.0	90	223	388				
2	16.9	-2.0	98	113	253				
3	-1.5	-6.9	77	207	470				
4	9.8	-6.8	62	302	159				
5	16.1	0.0	59	286	261				
6	0.8	-4.0	81	117	430				
7	-4.0	-8.0	92	97	455				
8	-3.8	-9.8	78	270	502				
9	1.8	-12.0	61	311	177				
10	9.3	-6.0	45	270	87				
11	9.2	-4.5	62	297	64				
12	15.4	-0.5	50	282	76				
13	6.0	-3.2	75	215	161				
14	9.5	-6.2	67	310	93				
15	11.5	-1.0	80	296	56				
16	9.0	-3.2	62	254	103				
17	9.0	-7.2	52	204	150				
18	16.9	5.6	55	148	175				
19	19.8	14.0	73	108	243				
20	19.1	1.7	74	217	190				
21	11.9	-5.0	60	290	198				
22	10.8	-2.1	60	286	96				
23	11.6	1.0	71	254	79				
24	4.8	-7.3	74	292	154				
25	14.0	-0.5	64	293	211				
26	8.0	-5.0	72	290	188				
27	8.0	-6.4	69	194	209				
28	12.0	2.6	73	172	257				
29	9.5	-7.0	99	39	169				
30	-7.0	-8.6	100	43	299		1.0	1.3	0.00
31	-8.0	-11.0	98	93	357		10.4	9.6	0.00
						TOTAL	11.4	10.9	0.00

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TABLE D-34. DAILY METEOROLOGICAL AND RUNOFF DATA FOR JANUARY, 1979

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	-8.3	-14.4		295	333				
2	-12.2	-16.7		309	270				
3	-3.3	-15.0		275	77				
4	-2.0	-7.2	97	96	43				
5	-8.9	-10.8	97	107	217		0.5	0.0	0.00
6	-6.3	-10.6	98	101	183		2.8	2.5	0.00
7	-6.1	-19.4	96	251	200				
8	-1.2	-19.4	69	331	77				
9	-0.6	-7.3	65	301	121				
10	-1.9	-7.3	96	125	241				
11	-1.1	-7.8	100	93	182				
12	3.6	-2.2	91	219	264				
13	0.0	-14.0	92	170	468		3.5	3.8	0.00
14	-8.9	-16.5	72	312	132				
15	1.7	-12.3	71	194	170				
16	5.7	-3.0	94	215	138				
17	5.7	-2.8	87	281	122				
18	10.2	-0.9	100	22	143		21.1	20.3	8.35
19	10.2	-1.0	100	133	88				
20	4.1	-1.9	85	227	344				
21	4.6	-1.0	67	309	254				
22	9.7	0.0	59	159	90				
23	4.2	-9.8	98	160	547		3.5	1.3	0.00
24	-2.2	-13.3	84	348	121				
25	1.9	-4.6	86	83	198		3.0	2.5	0.00
26	0.1	-6.2	100	134	351		2.5	1.3	0.00
27	-6.2	-11.1	90	341	169		0.8	0.0	0.00
28	-4.9	-12.2	86	365	92				
29	-3.1	-17.8	95	123	158		1.8	2.5	0.00
30	-6.4	-11.7	92	307	172		0.0	0.8	0.00
31	-4.8	-21.1	78	391	40				
						TOTAL	39.5	35.0	8.35

TABLE D-35. DAILY METEOROLOGICAL AND RUNOFF DATA FOR FEBRUARY, 1979

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	1.1	-22.7	73		56				
2	3.9	-7.5	96		335				
3	-4.0	-10.3	87	234	179				
4	-2.7	-12.1	82	288	200				
5	-4.2	-17.2	76	331	216				
6	-0.3	-4.2	97	107	93		3.0	2.5	0.00
7	-2.1	-13.0	79	411	230				
8	-0.2	-12.2	90	269	177				
9	-3.0	-21.7	73	418	277				
10	7.4	-8.2	78	414	105				
11	10.2	-2.1	92	318	76				
12	3.7	-2.6	97	135	150				
13	1.9	-6.2	100	128	98				
14	10.2	0.0	100	258	61				
15	1.4	-9.5	89	111	100				
16	-9.2	-14.0	70	219	235		1.3	3.8	0.00
17	-8.1	-11.9	94	83	174				
18	3.8	-9.1	75	443	251		0.8	1.3	0.00
19	10.1	-3.1	73	425	261		0.5	0.0	0.00
20	5.7	.9	100	90	272				
21	9.8	-2.3	90	251	127				
22	18.6	7.0	78	258	138				
23	12.1	-1.8	76	439	227				
24	1.9	-2.2	90	126	306				
25	2.0	-3.3	75	453	257				
26	11.7	-3.7	65	425	262				
27	14.9	1.8	62	352	177				
28	5.9	3.4	100	85	317		2.5	1.5	0.00
						TOTAL	8.1	9.2	0.00

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TABLE D-36. DAILY METEOROLOGICAL AND RUNOFF DATA FOR MARCH, 1979

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm²	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	14.9	2.9	77	380	116				
2	15.3	7.0	89		230		13.2	13.2	0.00
3	9.8	-1.0	90	114	232				
4	6.7	-2.7	66	486	354				
5	14.0	2.0	65	443	195				
6	17.2	0.1	76	438	58				
7	13.3	1.6	75	481	156				
8	15.2	-1.1	69	371	209				
9	16.7	1.7		352	344				
10	12.2	-1.1		493	206				
11	12.2	-1.1		519	117				
12	22.2	3.9		488	145				
13	17.6	6.7	60	509	309				
14	14.5	0.0	61	495	248				
15	11.9	2.0	74	263	119				
16	9.8	5.5	95	106	250		2.3	2.3	0.00
17	15.2	6.2	100	118	254		1.5	1.3	0.00
18	23.2	10.4	79		399		20.3	19.3	0.71
19	9.5	7.8	93		248		0.8	1.3	0.00
20	17.0	6.9	81	445	124				
21	19.5	8.6	93	231	130				
22	19.8	6.0	80	450	288		54.6	55.9	18.47
23	9.8	2.2	84	252	624		1.3	1.3	0.00
24	9.2	0.1	66	573	378				
25	17.4	-1.0	65	565	208				
26	17.3	3.2	68	557	192				
27	15.1	0.4	77	495	232				
28	22.1	15.0	90	305	225				
29	27.6	17.4	81	425	317				
30	19.5	6.2	74	535	428				
31	17.0	5.1	81	507	209				
						TOTAL	94.0	94.6	19.18

TABLE D-37. DAILY METEOROLOGICAL AND RUNOFF DATA FOR APRIL, 1979

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	9.3	4.6	99	148	332		3.0	3.0	0.00
2	10.0	1.2	74	514	235				
3	3.9	1.0	96	198	111		11.4	10.2	0.00
4	11.8	1.0	80	571	185				
5	22.0	3.5	68	620	84				
6	19.5	1.6	64	599	90				
7	25.4	14.3	69	544	188				
8	19.6	7.2	75	585	236				
9	16.1	3.0	67	605	283		0.5	0.5	0.00
10	16.3	6.7	96	154	135		27.4	25.4	2.18
11	19.2	12.0	54		332				
12	17.6	7.0	61		330				
13	19.6	7.4	55		111				
14	25.7	8.9	61		122				
15	28.3	14.5	54		132				
16	28.1	15.2	62		114				
17	25.5	16.6	62	457	183		4.6	3.5	0.00
18	16.3	13.4	98	106	228				
19	22.0	16.2	96	339	254				
20	19.0	13.5	99		219		1.8	2.0	0.00
21	20.9	10.0	72	593	122				
22	21.9	10.9	82	437	61				
23	21.8	12.9	87	443	145				
24	26.0	9.4	77	596	5				
25	25.8	9.8	80	577	245				
26	20.3	7.0	65	672	251				
27	14.0	7.0	78	309	108		2.5	2.5	0.00
28	14.4	4.0	84	265	85		2.3	2.5	0.00
29	19.6	4.6	73	653	88				
30	22.5	8.4	62	578	64				
						TOTAL	53,5	49.6	2.18

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TABLE D-38. DAILY METEOROLOGICAL AND RUNOFF DATA FOR MAY, 1979

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	18.5	11.9	92	325	121				
2	19.5	11.0	100	252	261		53.8	54.1	14.24
3	13.0	7.5	100	34	196		27.9	27.7	10.13
4	15.9	6.3	83	471	380		18.0	T7.0	8.36
5	21	5.3	73	700	130		0.0	0.0	0.41
6	26.7	12.4	70	700	299	6.1	0.0	0.0	0.11
7	27.6	17.8	78	717	375	8.1	0.0	0.0	0.03
8	26.8	19.0	85	631	523	9.9			
9	26.5	19.6	85	476	354	6.3			
10	23.8	9.5	95	185	208	7.6			
11	13.0	6.0	82	270	159	2.3			
12	22.5	5.0	70	702	72	5.1			
13	25.0	9.4	64	701	80	7.1			
14	28.5	14.1	56	705	53	3.8			
15	28.9	13.9	60	613	72	5.3			
16	28.0	16.1	64	671	156	11.2			
17	27.1	15.6	74	548	193	8.6			
18	26.4	16.8	83	496	278	4.3	4.3	4.3	0.00
19	28.9	17.9	86	652	204	9.6			
20	30.6	15.3		534	188	6.1	1.3	0.8	0.00
21	28.3	17.8		116	140	8.1	16.5	18.3	0.00
22	21.6	13.5	96	348	192	2.0	0.2	0.0	0.00
23	22.2	12.8	74	611	68	1.0			
24	21.1	8.3	69	632	116	7.9			
25	22.6	8.7	62	717	48	5.8			
26	23.1	14.6	85	442	51	7.9	1.3	0.8	0.00
27	28.8	17.4	82	705	71	4.1			
28	25.2	18.0	95	343	140	6.6	0.8	0.5	0.00
29	26.9	15.7	84	670	145	3.8			
30	25.6	16.1	92	394	119	5.8			
31	22.4	13.3	77	637	127	4.8			
						TOTAL	124.1	123.5	33.28

TABLE D-39. DAILY METEOROLOGICAL AND RUNOFF DATA FOR JUNE, 1979

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	23.5	13.9	78	554	108	5.6			
2	22.6	14.5	91	458	175	3.0			
3	26.8	12.5	75	707	82	6.6			
4	30.5	16.6	70	671	98	10.7			
5	25.9	18.1	98	239	117	1.8			
6	28.6	18.1	93	412	116	0.8			
7	32.2	18.6	85	646	142	1.3			
8	29.9	19.7	97	285	278		6.4	7.1	0.00
9	27.5	15.0	98	263	183		74.4	77.5	9.78
10	24.2	12.0	71	746	228				
11	27.2	13.2	67	751	55	1.3			
12	27.9	15.9	67	723	43	6.9			
13	30.4	16.8	70	712	195	9.6			
14	31.9	20.6	64	734	254	10.2			
15	31.0	20.8	71	717	463	14.0			
16	31.0	20.7	70	619	267	6.3			
17	29.5	22.2	76	461	354	7.1			
18	29.9	21.9	50	702	241	10.4			
19	29.0	23.1	87	399	138	8.1			
20	32.6	20.9	80	723	272	6.3			
21	31.9	20.7	89	433	164	7.6	0.5	0.8	0.00
22	30.3	19.1	89	422	193	8.1	25.1	25.6	0.00
23	28.7	20.9	96	354	156	2.5	17.0	16.8	0.53
24	24.9	19.0	95	300	87	3.8	3.8	2.5	0.05
25	25.4	17.6	96	334	74	3.6			
26	28.6	18.2	86	633	119	3.6			
27	30.0	21.0	82	693	95	3.6			
28	33.0	22.1	86	509	167	6.3	2.8	1.5	0.00
29	32.9	22.0	77	705	166	4.3			
30	28.5	20.6	85	456	95	10.7			
						TOTAL	130.0	131.8	10.36

TABLE D-40. DAILY METEOROLOGICAL AND RUNOFF DATA FOR JULY, 1979

Date	Air Temp Max. °C	Air Temp Min. °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap. mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	34.4	21.0	65	590	163	5.6			
2	33.0	23.5	67	683	240	8.6			
3	33.0	22.9	74	724	241	11.4			
4	34.8	23.2	71	709	209	10.2			
5	33.4	19.7	82	623	206	15.0	42.9	44.2	1.24
6	25.6	18.9	97	364	127	23.1	8.9	8.4	2.03
7	27.6	20.3	95	346	92	3.8			0.03
8	32.3	21.4	84	699	68	2.5			
9	33.6	22.9	77	553	95	8.1			
10	33.5	21.3	72	628	43	6.4			
11	31.3	21.9	78	673	69	6.4			
12	32.0	22.0	78	636	80	8.6			
13	32.8	23.4	76	694	76	6.1			
14	33.5	23.0	79	678	143	9.1			
15	31.0	23.4	91	514	90	6.1			
16	32.4	23.1	88	562	80	6.6			
17	25.2	20.0	100	265	88	10.2	76.2	87.6	23.60
18	23.8	20.6	98	204	134	2.3			0.08
19	27.7	18.7	76	543	56	2.5			0.03
20	29.6	18.0	77	630	58	3.6			
21	30.2	19.0	75	586	50	8.1			
22	30.6	21.2	80	521	109	4.1			
23	27.3	21.6	94	225	93	5.8			
24	31.5	23.0	85	602	93	4.1			
25	32.0	21.9	83	628	103	3.3	3.3	4.1	0.00
26	31.4	22.0	88	507	85	9.1			
27	31.0	20.9	83	515	109	6.1			
28	33.9	22.0	75	670	174	6.6			
29	35.1	25.7	75	556	175	7.6			
30	34.9	22.1	78	590	158	10.7	2.3	3.3	0.00
31	25.1	20.7	97	239	174	5.6	8.1	6.1	0.00
					TOTAL		141.7	153.7	27.01

TABLE D-41. DAILY METEOROLOGICAL AND RUNOFF DATA FOR AUGUST, 1979

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap. mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	29.9	18.3	77	567	85	5.8			
2	32.0	20.0	76	594	51	5.3			
3	32.4	21.2	82	566	122	9.1	1.5	2.5	0.00
4	34.5	22.4	68	650	127	8.4			
5	35.0	23.3	63	626	127	7.9			
6	34.9	23.9	64	671	-	8.4			
7	34.1	23.5	67	652	-	8.1			
8	33.6	22.9	70	631	-	9.1			
9	32.7	22.2	72	618	-	9.9			
10	34.6	18.0	79	552	-	11.4	12.2	13.7	0.00
11	26.1	16.6	71	673	127	2.3			
12	26.8	14.8	72	679	129	19.6			
13	32.0	17.7	76	648	114	1.5			
14	34.4	21.7	78	523	174	9.4			
15	27.2	16.2	88	487	163	10.2			
16	32.6	18.3	79	556	122	5.8			
17	32.8	21.9	71	614	154	7.1			
18	33.9	22.9	67	620	177	10.2			
19	35.0	21.7	79	466	100	7.4			
20	29.4	18.2	78	495	298	-	3.6	3.6	0.00
21	32.0	16.7	83	581	163	-	9.9	10.7	0.00
22	30.8	17.4	82	603	167	-	2.0	3.8	0.00
23	29.5	18.6	74	616	48	-			
24	31.0	18.5	80	537	103	11.2	5.1	5.1	0.00
25	28.0	18.7	91	337	138	2.5	17.0	15.7	0.00
26	27.7	19.9	88	375	71	5.3			
27	29.5	18.8	89	361	80	3.0			
28	33.4	20.0	73	600	31	3.0			
29	33.2	21.9	73	602	130	10.7			
30	33.3	21.8	75	593	116	9.9			
31	25.8	20.0	100	156	121	6.9	18.5	21.6	0.00
					TOTAL		69.8	76.7	0.00

TABLE D-42. DAILY METEOROLOGICAL AND RUNOFF DATA FOR SEPTEMBER, 1979

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm^2	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	32.0	18.8	83	590	121	-	35.8	33.5	0.00
2	30.0	17.6	81	-	103	-	3.0	8.4	0.00
3	30.5	21.4	80	516	127	19.6			
4	31.2	21.8	76	555	51	7.4			
5	31.8	21.8	78	565	82	7.4			
6	29.2	19.0	88	357	98	2.0	17.5	18.3	0.00
7	27.3	18.7	71	573	90	2.8			
8	29.0	14.5	65	577	119	15.0			
9	29.0	16.0	66	577	39	9.1			
10	29.4	16.5	71	599	130	5.6			
11	28.9	15.3	74	492	82	5.6			
12	29.8	17.1	74	471	56	2.8			
13	24.9	14.5	64	518	117	7.9			
14	22.2	9.4	68	408	206	9.7			
15	24.2	11.8	62	571	93	1.8			
16	25.2	9.8	59	578	45	4.3			
17	27.0	10.8	60	548	60	7.1			
18	27.9	10.7	70	526	37	3.3			
19	26.5	15.2	81	341	61	6.1			
20	22.8	16.5	95	140	51	3.0			
21	25.2	14.8	67	420	50	2.0			
22	27.0	10.7	58	532	113	6.6			
23	29.0	15.1	73	494	103	4.6			
24	29.9	16.1	75	493	60	5.3			
25	30.1	16.4	65	456	121	5.8			
26	30.0	14.9	65	485	61	6.1			
27	29.4	17.3	74	470	119	6.6			
28	29.3	18.0	70	322	145	5.6			
29	32.8	13.0	62	523	40	12.2			
30	33.9	17.1	57	471	39	4.3			
					TOTAL		56.3	60.2	0.00

TABLE D-43. DAILY METEOROLOGICAL AND RUNOFF DATA FOR OCTOBER, 1979

Date	Air Temp		Rel Humid	Solar Radiation	Wind Travel	Pan Evap	Rainfall		Runoff
	Max °C	Min °C	%	Cal/cm²	km	mm	Gage 1 mm	Gage 2 mm	mm
1	28.3	13.4	51	457	74	5.8			
2	27.7	7.7	49	487	174	10.9			
3	22.4	11.0	48	381	148	7.6			
4	21.5	6.8	53	478	182	8.6			
5	29.0	7.6	51	449	71	6.8			
6	27.9	11.7	48	461	167	6.3			
7	33.1	14.0	48	435	120	7.4			
8	34.5	20.6	53	443	122	7.4			
9	14.4	6.2	63	250	347	9.1			
10	21.0	2.7	63	380	92	5.3			
11	31.9	12.2	49	458	174	7.6			
12	26.0	14.3	58	386	88	6.6			
13	15.6	7.1	60	436	225	5.6			
14	18.3	8.5	55	245	243	5.3			
15	20.9	12.1	84	172	224	8.6	14.5	13.2	0.00
16	22.1	14.7	94	235	179	0.8			
17	26.0	15.1	86	292	113	1.3			
18	28.0	17.4	77	346	100	1.5			
19	27.7	19.9	80	374	92	9.9			
20	32.7	21.5	65	425	655	5.1			
21	29.6	11.6	82	314	433	10.9	11.7	11.7	0.00
22	13.5	5.3	77	290	386	11.7			
23	19.8	2.7	64	414	161	2.5			
24	25.0	7.7	51	410	50	3.0			
25	26.2	8.6	50	406	39	3.3			
26	25.6	8.7	56	412	142	4.8			
27	24.4	11.8	71	360	124	5.6			
28	21.9	6.8	64	400	95	6.6			
29	19.9	6.9	94	321	92	5.8			
30	19.4	8.2	90	84	360	1.5	11.4	9.9	0.00
31	8.8	4.5	79	160	365	2.3			
						TOTAL	37.6	34.8	0.00

TABLE D-44. DAILY METEOROLOGICAL AND RUNOFF DATA FOR NOVEMBER, 1979

Date	Air Temp Max °C	Air Temp Min °C	Rel Humid %	Solar Radiation Cal/cm²	Wind Travel km	Pan Evap mm	Rainfall Gage 1 mm	Rainfall Gage 2 mm	Runoff mm
1	12.7	0.8	67	352	188				
2	12.0	3.8	86	193	66				
3	16.7	0	59	384	63				
4	17.6	6.0	54	284	88				
5	14.6	5.4	73	338	323				
6	8.4	0.2	77	362	339				
7	7.6	-0.2	97	80	69		2.8	3.3	0.00
8	9.7	7.0	100	74	158		8.6	8.4	0.00
9	8.9	1.2	83	181	166		8.1	6.8	0.00
10	4.6	-2.1	75	208	254				
11	8.0	-3.8	71	227	61				
12	10.4	0.2	78	264	58				
13	12.8	-0.9	67	352	72				
14	15.9	1.0	67	330	47				
15	19.4	2.8	61	352	61				
16	21.0	2.2	60	334	95				
17	20.3	6.3	76	279	77				
18	21.3	13.0	89	221	190				
19	23.5	11.5	70	314	286				
20	20.0	14.2	100	66	108		52.3	54.3	0.83
21	14.2	1.6	85	272	211		5.3	5.8	0.01
22	4.6	-1.4	80	170	259				
23	11.1	-3.0	66	349	96				
24	14.5	1.0	68	304	53				
25	13.0	2.4	78	225	106				
26	13.0	-0.5	67	305	130				
27	13.7	-0.2	88	213	180				
28	1.2	-2.6	73	271	183				
29	-0.5	-6.3	79	295	267				
30	6.0	-7.1	68	233	143				
					TOTAL		77.1	78.6	0.84

TABLE D-45. DAILY METEOROLOGICAL AND RUNOFF DATA FOR DECEMBER, 1979

	Air Temp		Rel	Solar	Wind	Pan	Rainfall		
Date	Max °C	Min °C	Humid %	Radiation Cal/cm^2	Travel km	Evap mm	Gage 1 mm	Gage 2 mm	Runoff mm
1	6.3	-3.8	72		53.6				
2	6.4	-6.6	70		157.7				
3	15.0	-0.7	58	227.9	164.2				
4	16.0	-1.0	66	287.9	104.6				
5	16.6	1.9	55	258.0	103.0				
6	13.7	-2.2	62	284.8	189.9				
7	15.0	1.8	58	279.9	117.5				
8	9.3	-2.0	62	251.6	115.9				
9	16.7	3.0	56	251.4	151.3				
10	19.0	6.9	83	265.7	183.5				
11	12.8	-1.4	84	111.2	257.5				
12	-1.8	-4.4	74	73.5	283.2				
13	7.2	-6.0	68	254.7	334.7				
14	7.6	-1.1	70	202.8	85.3				
15	8.9	0.5	96	186.6	77.2				
16	1.0	-11.3	63	269.4	186.7				
17	2.0	-16.7	50	311.6	270.4				
18	14.2	-3.4	50	288.5	143.2				
19	15.0	-2.0	75	265.4	49.9				
20	14.7	1.0	81	266.0	78.8				
21	16.8	2.9	89	199.0	96.6				
22	19.8	9.7	63	245.2	82.1				
23	9.8	4.8	88	76.6	114.2				
24	10.7	1.5	79	329.2	307.4				
25	14.8	-2.6	73	292.0	78.8				
26	11.8	3.0	80	206.1	159.3				
27	10.6	5.2	89	131.7	82.1				
28	9.3	3.4	100	47.0	215.8		43,18	41.91	0.54
29	3.4	2.0	100	60.4	156.1		3.81	3.30	0.00
30	3.3	-0.1	96	96.4	194.7				
31	7.4	-0.3	91	276.6	119.1				
					TOTAL		46.99	45.21	0.54

APPENDIX E

SEDIMENT AND NUTRIENT ANALYSIS DATA FOR RUNOFF FROM HYDROLOGIC EVENTS IN 1977, 1978 AND 1979

TABLE E-1. SEDIMENT AND NUTRIENT ANALYSIS OF RUNOFF FROM EVENT OF 20-21 MAY, 1977

Runoff Began: 20 May, 1977 (2120); Runoff Ended: 21 May, 1977 (2124); Runoff Amount: 44.27 mm

Analysis by: COD and TOC tests by Dr. S. L. Burks
BOD tests by Animal Science Dept.
All other tests by: Water testing Laboratory
Agronomy Dept.

Sample No.	Time	Runoff Rate m^3/s	Accum. Runoff mm	Sed Load mg/l	N in Sed. mg/g	NH_4-N	NO_3-N	NO_2-N	Diss. P	Total P	Diss. K	Total K	COD	TOC	BOD
						mg/l									
1	2147	1.46	2.29	1273	4.8	<0.08	0.31		0.05	0.05	4.5		40.3	13.5	
2	2157	4.12	4.95	3674	3.6	0.04	0.84		<0.01	-	2.9		40.1	11.9	3.42
3	2207	6.27	9.96	2163	3.4	<0.08	<0.08		0.01	0.01	2.7		33.1	11.2	
4	2217	4.64	16.48	2378	2.6	<0.08	0.15		0.02	0.02	4.3		26.8	9.4	
5	2227	2.54	20.14	1260	4.0	0.15	0.23		<0.01	0.01	3.8		25.8	8.3	2.87
6	2237	1.68	22.17	693	6.7	<0.08	0.23		<0.01	0.01	3.3		69.0	10.4	
7	2247	1.38	23.72	4869	3.1	<0.08	<0.08		<0.01	0.01	3.0		27.0	11.4	
8	2257	1.26	25.04	1052	4.4	<0.08	<0.08		<0.01	0.01	3.1		26.0	8.4	2.10
9	2307	1.25	26.34	951	5.5	<0.08	<0.08		<0.01	0.01	3.0		27.2	9.0	
10	2317	1.29	27.81	687	7.5	<0.08	<0.08		<0.01	0.01	3.0		26.2	9.5	
11	2327	1.32	29.16	618	7.2	<0.08	<0.08		<0.01	0.01	3.0		24.2	8.9	0.70
12	2337	1.24	30.58	635	10.2	<0.08	<0.08		<0.01	0.01	3.0		24.2	9.5	
13	2124 (21 May)	0.00	44.27	635	10.2	<0.08	<0.08		<0.01	0.01	3.0				

TABLE E-2. SEDIMENT AND NUTRIENT ANALYSIS OF RUNOFF FROM EVENT OF 23 MAY, 1977

Runoff Began: 23 May, 1977 (0526); Runoff Ended: 24 May, 1977 (1520); Runoff Amount: 13.56 mm

Analysis by: COD and TOC tests by Dr. S. L. Burks
BOD tests by Animal Science Dept.

All Other tests by: Water Testing Laboratory
Agronomy Dept.

Sample No	Time	Runoff Rate	Accum. Runoff	Sed. Load	N in Sed.	NH_4-N	NO_3-N	NO_2-N	Diss. P	Total P	Diss. K	Total K	COD	TOC	BOD
		m^3/s	mm	mg/l	mg/g					mg/l					
1	0538	0.06	0.01	362	11.3	< 0.08	< 0.08		0.25	0.26	3.1		27.1	14.8	
2	0548	0.26	0.18	1506	5.1	0.23	< 0.08		< 0.01	< 0.02	3.3		34.1	13.4	1.65(1)
3	0558	0.33	0.58	1190	6.8	< 0.08	< 0.08		< 0.01	< 0.02	4.6		42.4	13.7	
4	0608	0.29	0.89	819	5.9	0.53	0.92		< 0.01	< 0.02	3.7		41.2	15.4	
5	0618	0.24	1.17	460	8.7	< 0.08	0.38		0.01	750(2)	4.2		45.0	15.9	4.75
6	0628	0.20	1.35	371	10.0	< 0.08	0.61		< 0.01	< 0.02	3.8		48.6	16.1	
7	0638	0.15	1.52	278	19.4	< 0.08	< 0.08		0.01	1100(2)	3.7		45.0	16.0	
8	0648	0.13	1.73	637	6.8	< 0.08	< 0.08		< 0.01	< 0.02	3.2		48.0	16.3	3.87
9	0658	0.23	1.90	1209	6.3	< 0.08	< 0.08		< 0.01	< 0.02	4.5		49.9	15.7	
10	0708	0.41	2.16	1609	3.9	< 0.08	< 0.08		< 0.01	< 0.02	4.4		45.2	14.9	
11	0718	0.66	2.87	1303	4.8	< 0.08	< 0.08		0.02	< 0.03	4.0		40.4	12.8	2.40
12	0728	0.85	3.56	1760											
13	0738	1.09	4.60	2300											
14	0748	1.21	5.82	2500											
15	0808	0.94	8.03	2120											
16	0831	0.54	9.73	1550											
17	0900	0.26	10.87	600	–	< 0.08	< 0.08		0.04	< 0.05	3.0		30.95	11.7	
18	0925	0.17	11.46	380											
19	1004	0.10	11.96	100											
20	1053	0.06	12.32	100											
21	2400	0.002	13.21	100											
22	1520	0.00	13.56	100											

Notes:

1. All composite samples for BOD are a blend of 3 adjacent samples.
2. High readings of P may have been caused by chunks of organic matter in form of leaves, dung, etc.
3. Sampler capacity exceeded after 0718 hours; all subsequent sediment loads except at 0900 hours are best estimates based on sediment/runoff rate relationship.

TABLE E-3. SEDIMENT AND NUTRIENT ANALYSIS OF RUNOFF FROM EVENT OF 27 MAY, 1977

Runoff Began: 27 May, 1977 (0210); Runoff Ended: 27 May, 1977 (2200); Runoff Amount: 1.85 mm

Analysis by: COD and TOC tests by Dr. S. L. Burks; BOD tests by Animal Science Dept. All other tests by: Water Testing Laboratory Agronomy Dept.

Sample No.	Time	Runoff Rate	Accum. Runoff	Sed. Load	N in Sed	NH_4-N	NO_3-N	NO_2-N	Diss. P	Total P	Diss. K	Total K	COD	TOC	BOD
		m^3/s	mm	mg/l	mg/g	mg/l									
1	0222	0.032	0.01	2132	1.2	<0.08	<0.08		0.01	0.01	3.9		37.3	16.1	
2	0242	0.105	0.04	1315	4.9	<0.08	0.15		<0.01	<0.02	3.5		45.6	14.5	6.53
3	0302	0.118	0.12	802	6.9	<0.08	0.15		0.01	<0.02	4.8		50.9	18.0	
4	0322	0.114	0.66	261	9.1	0.92	0.69		0.01	<0.02	5.3		54.2	19.7	
5	0342	0.093	0.86	316	14.1	<0.08	0.53		0.01	<0.02	5.6		54.6	20.2	6.25
6	0402	0.073	1.04	238	12.1	<0.08	0.53		0.01	<0.02	4.8		47.7	20.0	
7	0422	0.053	1.17	223	19.3	<0.08	<0.08		0.01	<0.02	4.8		43.1	20.4	6.70
8	0442	0.041	1.27	196	21.9	<0.08	<0.08		0.02	<0.03	4.4		33.6	20.2	
9	0502	0.028	1.35	217	20.3	<0.08	<0.08		0.01	<0.02	5.0			20.4	
10	2200	0.000	1.85	68	57.8	<0.08	<0.08		0.02	<0.03	4.6			20.5	

TABLE E-4. SEDIMENT AND NUTRIENT ANALYSIS OF RUNOFF FROM EVENT OF 1 JULY, 1977

Runoff Began: 1 July, 1977 (0454); Runoff Ended: 1 July, 1977 (1400); Runoff Amount: 1.72 mm

Analysis by: TOC tests by Dr. S. L. Burks   All other tests by: Water testing Laboratory Agronomy Dept.

Sample No.	Time	Runoff Rate	Accum. Runoff	Sed. Load	N In Sed.	NO_4-H	NO_3-N	NO_2-N	Diss. P	Total P	Diss. K	Total K	COD	TOC	BOD
		m^3/s	mm	mg/l	mg/g	mg/l									
1	0502	0.29	0.11	1760	10.3	< 0.08	0.08		0.01		3.8			14.8	
2	0523	0.30	0.84	2515	4.1	< 0.08	< 0.08		0.02		2.9			14.2	
3	0543	0.11	1.27	1841	4.0	< 0.08	< 0.08		0.02		3.0			13.6	
4	0602	0.61	1.40	1322	5.0	< 0.08	< 0.08		0.03		2.8			13.0	
5	0622	0.28	1.52	1153	4.4	< 0.08	< 0.08		0.04		2.8			13.8	
6	0643	0.02	1.58	889	6.8	< 0.08	< 0.08		0.06		3.1			13.2	
7	0703	0.12	1.60	853	6.0	< 0.08	< 0.08		0.04		3.0			14.1	
8	0723	0.01	1.63	734	5.6	< 0.08	< 0.08		0.07		3.5			13.3	
-	1400	0.00	1.72	734											

TABLE E-5. SEDIMENT AND NUTRIENT ANALYSIS OF RUNOFF FROM EVENT OF 5 JUNE, 1978

Runoff Began: 5 June, 1978 (0550); Runoff Ended: 5 June, 1978 (1400); Runoff Amount: 4.42 mm
Analysis by: Nitrogen tests by: Dr. D. W. Toetz. All other tests by: Dr. S. L. Burks.

Sample No.	Time	Runoff Rate	Accum. Runoff	Sed. Load	N in Sed.	NH_4-N	NO_3-N	NO_2-N	Diss. P	Total P	Diss. K	Total K	COD	TOC
		m^3/s	mm	mg/l	mg/g	mg/l								
1	0554	0.057	0.005			0.425	0.023		0.000	0.083		15.58	80.6	20.45
2	0604	0.555	0.381			0.254	0.298		0.035	0.750		31.65	102.4	15.58
3	0613	0.685	0.889			0.191	0.105		0.024	0.035		27.99	140.3	16.22
4	0622	0.645	1.600			0.351	0.081		0.083	0.120		27.18	123.4	16.10
5	0630	0.608	2.134			0.127	0.139		0.000	0.000		28.37	89.5	15.30
6	0640	0.385	2.540			0.092	0.031		0.005	0.012		20.50	79.8	14.58
7	0648	0.284	2.845			0.097	0.095		0.002	0.153		25.74	68.5	15.32
8	0702	0.203	3.175			0.096	0.029		0.059	0.023		10.82	65.9	13.88
9	0718	0.130	3.454			0.147	0.029		0.073	0.087		10.82	57.9	14.38
10	0740	0.085	3.708			0.170	0.021		0.002	0.002		8.36	56.1	16.72
11	0807	0.053	3.886			0.166	0.019		0.047	0.035		6.88	50.4	17.55
12	0833	0.036	4.013			0.193	0.023		0.026	0.073		6.88	52.0	17.82
13	0904	0.024	4.115			0.207	0.019		0.035	0.038		6.06	52.0	17.17
14	1400	0.000	4.420			0.012	0.020		0.012	0.024		5.08	53.7	20.53

TABLE E-6. SEDIMENT AND NUTRIENT ANALYSIS OF RUNOFF FROM EVENT OF 21-22 JUNE, 1978

Runoff Began: 21 June, 1978 (1810); Runoff Ended: 22 June, 1978 (0140); Runoff Amount: 0.09 mm

Analysis by: Nitrogen tests by: Dr. D. W. Toetz. All other tests by: Dr. S. L. Burks.

Sample No.	Time	Runoff Rate	Accum. Runoff	Sed Load	N in Sed	NH_4-N	NO_3-N	NO_2-N	Diss. P	Total P	Diss. K	Total K	COD	TOC
		m^3/s	mm	mg/l	mg/g	mg/l								
1	1842	0.001	0.003			0.060	0.134	0.024	0.051	0.096		15.59	74.3	29.98
2	1854	0.002	0.005			N D	0.113	0.014	0.000	0.005		24.54	66.5	29.16
3	1903	0.003	0.008			0.010	0.128	0.017	0.014	0.084		12.94	82.1	30.31
4	1912	0.004	0.010			0.042	0.117	0.014	0.037	0.140		19.25	78.2	30.15
5	1922	0.004	0.013			0.066	0.113	0.016	0.000	0.051		22.71	74.3	29.49
6	1931	0.004	0.018			0.046	0.117	0.019	0.005	0.014		18.23	74.3	30.15
7	1940	0.004	0.020			N D	0.217	0.017	0.005	0.061		21.49	78.2	31.30
8	1950	0.004	0.025			N D	0.128	0.019	0.051	0.061		17.22	78.2	31.46
9	1958	0.004	0.030			0.044	0.119	0.021	0.007	0.021		22.30	74.3	29.49
10	2008	0.004	0.033			0.034	0.111	0.014	0.049	0.049		17.42	74.3	28.18
11	2016	0.003	0.036			0.046	0.126	0.013	0.044	0.086		21.89	74.3	31.38
12	2026	0.003	0.038			0.062	0.109	0.015	0.119	0.037		22.10	70.4	33.51
13	2035	0.002	0.046			0.152	0.115	0.008	0.096	0.021		21.49	62.6	30.22
--	0140	0.000	0.091											

TABLE E-7. SEDIMENT AND NUTRIENT ANALYSIS OF RUNOFF FROM EVENT OF 14-15 NOVEMBER, 1978

Runoff Began: 14 November, 1978 (1923); Runoff Ended: 15 November, 1978 (0820), Runoff Amount: 0.94 mm

Analysis by: Nitrogen tests by: None Made . All other tests by Dr. S. L. Burks.

Sample No.	Time	Runoff Rate	Accum. Runoff	Sed. Load	N in Sed.	NH_4-N	NO_3-N	NO_2-N	Diss. P	Total P	Diss. K	Total K	COD	TOC
		m^3/s	mm	mg/l	mg/g	mg/l								
1	1923	0.006	0.003	562					-	0.081	3.88	10.82	70.2	36.2
2	1936	0.089	0.066	865					-	0.100	4.22	14.91	116.6	37.8
3	1947	0.109	0.180	813					-	0.089	3.94	14.46	61.2	29.9
4	1956	0.105	0.284	807					-	0.005	3.74	13.58	57.6	30.6
5	2006	0.085	0.386	866					0.107	0.191	4.15	-	57.6	30.6
6	2016	0.069	0.457	885					0.021	0.089	3.26	16.16	54.0	30.6
7	2026	0.057	0.533	807					0.081	0.087	3.54	14.90	66.9	30.6
8	2036	0.049	0.584	787					0.032	0.055	3.60	13.10	52.5	27.7
9	2045	0.041	0.635	729					0.001	0.001	3.19	15.58	56.8	27.7
10	2055	0.028	0.660	657					0.047	0.087	3.54	14.39	70.7	28.8

(Continued)

TABLE E-7 (Continued)

Runoff Began: 14 November, 1978 (1923); Runoff Ended: 15 November, 1978 (0820), Runoff Amount: 0.94 mm
Analysis by: Nitrogen tests by: None Made . All other tests by Dr. S. L. Burks.

Sample No.	Time	Runoff Rate	Accum. Runoff	Sed. Load	N in Sed.	NH_4-N	NO_3-N	NO_2-N	Diss. P	Total P	Diss. K	Total K	COD	TOC
		m^3/s	mm	mg/l	mg/g					mg/l				
11	2105	0.024	0.706	662					0.173	0.252	3.47	13.13	68.8	25.9
12	2115	0.020	0.711	595					0.099	0.032	3.33	12.48	78.7	26.4
13	2125	0.016	0.737	642					0.095	0.095	3.19	11.33	57.6	27.1
14	2135	0.012	0.762	579					0.064	0.064	3.12	11.77	56.8	25.6
15	2146	0.012	0.770	586					0.039	<0.002	3.12	11.43	57.2	26.5
16	2157	0.010	0.782	621					<0.002	0.084	2.92	11.39	57.6	25.9
17	2209	0.009	0.792	513					0.066	0.211	3.19	12.69	57.6	25.2
18	2221	0.007	0.803	545					0.081	0.089	3.33	11.46	59.5	25.7
19	0820 (15 Nov.)	0.000	0.940	370					0.096	0.096	4.36	10.96	56.5	28.30

TABLE E-8. SEDIMENT AND NUTRIENT ANALYSIS OF RUNOFF FROM EVENT OF 18 MARCH, 1979

Runoff Began: 18 March, 1979 (1046); Runoff Ended: 18 March, 1979 (2200) Runoff Amount: 0.56 mm

Analysis by: Nitrogen tests by: Dr. D. W. Toetz. All other tests by Dr. S. L. Burks.

Sample No	Time	Runoff Rate	Accum. Runoff	Sed Load	N in Sed	NH_4-N	NO_3-N	NO_2-N	Diss. P	Total P	Diss. K	Total K	COD	TOC
		m^3/s	mm	mg/l	mg/g	mg/l								
1	1101	0.016	0.005	1828	0.771	0.654	0.141	0.008	0.005	0.492	3.46	26.53	184.0	73.1
2	1133	0.028	0.076	3760	0.708	0.806	0.245	0.011	0.167	0.302	3.28	37.30	211.8	85.4
3	1213	0.020	0.305	1984	0.640	0.625	0.198	0.011	0.108	0.468	2.92	27.60	177.1	56.6
4	1318	0.008	0.483	1332	0.992	0.515	0.134	0.008	0.105	0.420	3.10	21.15	107.6	37.0
5	1430	0.002	0.508	980	0.991	0.821	0.147	0.007	0.106	0.348	3.46	16.84	73.0	35.7
6	1548	0.001	0.317	736	0.664	0.225	0.145	0.007	0.153	0.364	3.46	12.07	128.6	34.3
7	1843	0.000	0.533	616	3.199(1)	0.797	0.074	0.006	0.089	0.313	3.28	9.20	100.7	27.0
8	2200	0.000	0.559	508	1.782(1)	0.897	0.064	0.006	0.126	0.306	3.46	8.49	55.5	30.6
Grab(2)				132	1.511(1)	0.539	1.987(1)	0.093(1)	0.055	0.140	1.66	2.38	66.0	13.0

Notes:

1. Values of N for these three samples appear to be very high with no readily apparent explanation.
2. This grab sample was obtained from the H-flume at the southeast corner of the exclosure located in the southwest corner of the watershed. Note that this is the exclosure from which cows had been excluded and dung had been physically removed.

TABLE E-9. SEDIMENT AND NUTRIENT ANALYSIS OF RUNOFF FROM EVENT OF 22-23 MARCH, 1979

Runoff Began: 22 March, 1979 (0500), Runoff Ended: 23 March 1979 (1400), Runoff Amount: 16.43 mm.
Analysis by: Nitrogen tests by: Dr. D. W. Toetz. All other tests by: Dr. S. L. Burks.

Sample No	Time	Runoff Rate	Accum. Runoff	Sed Load	N in Sed	NH_4-N	NO_3-H	NO_2-N	Diss. P	Total P	Diss. K	Total K	COD	TOC
		m^3/s	mm	mg/l	mg/g	mg/l								
1	0528	0.146	0.076	1104	0.587	0.434	0.022	0.001	0.065	0.528	3.28	11.72	108.4	46.3
2	0546	0.304	0.559	3469	0.612	0.806	0.029	0.004	0.089	0.671	3.10	25.45	228.9	65.7
3	0606	0.539	1.448	2808	0.726	0.539	0.029	0.006	0.107	0.607	2.74	20.07	164.6	58.6
4	0637	0.896	3.759	3788	0.626	1.007	0.048	0.007	0.137	0.677	2.38	27.07	192.8	70.7
5	0710	1.220	7.061	3828	0.567	0.501	0.041	0.007	0.125	0.589	2.02	19.53	124.5	40.3
6	0737	0.766	10.262	2544	0.592	0.597	0.046	0.007	0.028	0.529	2.02	8.48	120.5	30.2
7	0813	0.430	12.497	1429	0.641	0.453	0.042	0.006	0.069	0.416	2.38	9.02	-	30.2
8	0839	0.308	13.513	756	0.462	0.754	0.064	0.006	0.081	0.292	2.57	6.69	40.2	25.0
9	1430	0.008	15.697	236	N D	0.129	0.061	0.004	0.014	0.165	3.64	2.74	28.1	38.1
10	1400 (23 Mar.)	0.000	16,434	108	0.455	0.058	0.119	0.003	0.026	0.129	3.99	1.66	28.1	-
Grab				172	1.023	0.606	0.039	0.004	0.014	0.183	3.82	2.56	28.1	21.1

TABLE E-10. SEDIMENT AND NUTRIENT ANALYSIS OF RUNOFF FROM EVENT OF 2-7 MAY, 1979

Runoff Began: 2 May, 1979 (0852); Runoff Ended: 7 May, 1979 (1730); Runoff Amount: 32.03 mm

Analysis by: Nitrogen tests: Dr. D. W. Toetz. All other tests by: Dr. S. L. Burks

Sample No	Time	Runoff Rate m^3/s	Accum. Runoff mm	Sed. Load mg/l	N in Sed. mg/g	NH_4-N	NO_3-N	NO_2-N	Diss. P	Total P	Diss. K	Total K	COD	TOC	BOD
						mg/l									
1	0904	0.105	0.076	1482	1.71	0.441	0.053	ND	0.330	0.438	5.36	17.55	122.8	34.1	
2	0914	0.138	0.203	2058	1.68	0.462	0.080	ND	0.221	0.533	5.61	17.32	122.8	44.1	
3	0924	0.134	0.356	2253	1.52	0.343	0.099	ND	0.225	0.533	4.20	17.79	130.2	45.8	
4	0932	0.122	0.457	2032	2.07	0.511	0.092	ND	0.248	0.601	3.54	16.57	130.2	43.2	
5	0954	0.093	0.711	1248	2.17	0.283	0.073	ND	0.248	0.533	5.28	16.99	119.0	45.0	
6	1017	0.077	0.889	721	3.79	0.426	0.053	ND	0.170	0.506	4.20	14.79	93.0	34.5	
7	1047	0.065	1.118	501	3.75	0.418	0.031	ND	0.194	0.411	4.12	13.39	85.6	33.3	
8	1112	0.073	1.295	415	3.32	0.250	0.032	ND	0.227	0.379	4.04	10.89	81.8	28.7	
9	1152	0.065	1.600	254	3.47	0.371	0.039	ND	0.227	0.330	4.37	7.24	78.1	29.0	
10	2034	1.707	4.191	1967	1.81	0.264	0.009	ND	0.140	0.631	3.51	14.30	167.4	55.9	
11	2038	1.808	4.928	5484	1.22	0.274	0.009	ND	0.075	0.778	3.05	28.60	290.2	69.6	
12	2050	1.480	6.985	5167	1.69	0.223	0.011	ND	0.103	0.745	2.86	30.19	235.6	46.5	
13	2057	1.168	7.950	3239	2.44	0.331	0.013	ND	0.022	0.698	2.36	21.72	152.5	51.2	
14	2110	0.722	9.246	2242	1.57	0.289	0.013	ND	0.070	0.679	2.55	14.83	122.8	39.6	
15	2120	0.539	9.906	1556	1.28	0.248	0.010	ND	0.070	0.508	2.42	13.77	81.8	31.3	
16	2134	0.373	10.592	1337	1.91	0.102	0.009	ND	0.100	0.409	2.74	12.18	81.8	33.7	
17	2152	0.264	11.176	796	1.94	0.050	0.007	ND	0.062	0.466	2.74	7.42	70.7	22.7	
18	2207	0.203	11.532	520	6.01	0.078	0.012	ND	0.077	0.328	2.74	5.30	59.5	22.5	
19	2222	0.162	11.811	721	2.36	0.052	0.012	ND	0.286	0.229	3.87	4.50	55.8	20.4	
20	2252	0.097	12.192	319	2.12	0.250	0.008	ND	0.125	0.366	2.61	2.65	59.5	23.3	
21	2254 (2 May)	0.093	12.243	280	2.70	0.034	0.009	ND	0.115	0.366	2.86	3.18	85.6	19.5	
Grab (1)	1315	Pasture		19	11.03	0.240	0.019	ND	0.057	0.002	2.86	3.24	40.9	16.1	
Grab (2)	1320	Pasture		134	10.45	0.066	0.018	ND	0.052	0.153	2.61	4.03	63.2	25.4	
Grab (3)	1325	Road Ditch		1923	0.97	0.191	0.024	ND	0.012	0.461	2.24	10.65	126.5	35.6	
Grab (4)	1330 (3 May)	Exclosure		21	6.88	0.184	0.016	ND	0.027	0.002	3.81	5.09	63.2	26.3	

(Continued)

TABLE E-10 (Continued)

Notes:

1. Sample obtained from water flowing through grass in a small natural drainageway 50 m south of soil water station 27; no visible erosion in channel or upstream area.

2. Sample obtained from a small ponded area in a natural surface depression 5 cm x 3 m x 5 m located 90 m east of soil water station 27; no visible erosion in surrounding area.

3. Sample obtained from water flowing in field road ditch at transit station 120 m north of soil water station 16; represents runoff from recently graded field road.

4. Sample obtained from outflow from H flume located 90 m northeast of soil water station 17; represents runoff from an exclosure from which cows had been excluded and dung had been physically removed.

APPENDIX F

COMPUTATION OF SEDIMENT LOST BY RUNOFF FROM HYDROLOGIC EVENTS IN 1977, 1978 AND 1979

TABLE F-1. SEDIMENT LOST BY RUNOFF FROM EVENT OF 20 MAY, 1977

Rainfall: 101.55 mm Runoff: 44.27 mm
Sediment/Runoff Ratio: 15.53 kg/ha/mm

Sample No.	Time	Runoff Rate m^3/s	Runoff Rate mm/h	Accum. Runoff mm	Sed. Load in Sample mg/l	Sed. per Interval kg/ha	Accum. Sed. Loss kg/ha
1	2147	1.456	9.12	2.28	1273	29.10	29.10
2	2157	4.115	25.78	4.95	3674	65.96	95.06
3	2207	6.268	39.27	9.95	2163	146.03	241.10
4	2217	4.638	29.06	16.48	2378	148.21	389.31
5	2227	2.538	15.90	20.14	1260	66.53	455.85
6	2237	1.675	10.49	22.17	693	19.84	475.69
7	2247	1.379	8.64	23.72	4869	43.08	518.78
8	2257	1.261	7.90	25.04	1052	39.10	557.88
9	2307	1.249	7.82	26.34	951	12.97	570.85
10	2317	1.293	8.10	27.81	687	12.06	582.92
11	2327	1.322	8.28	29.15	618	8.78	591.70
12	2337	1.245	7.80	30.59	635	8.91	600.61
13	2124 (21 May)	0.000	0.00	44.27	635	86.93	687.55

TABLE F-2. SEDIMENT LOST BY RUNOFF FROM EVENT OF 23 MAY, 1977

Rainfall: 38.50 mm Runoff: 13.56 mm
Sediment/Runoff Ratio: 14.28 kg/ha/mm

Sample No.	Time	Runoff Rate m^3/s	Runoff Rate mm/h	Accum. Runoff mm	Sed. Load in Sample mg/l	Sed. per Interval kg/ha	Accum. Sed. Loss kg/ha
1	0538	0.057	0.36	0.01	362	0.03	0.03
2	0548	0.259	1.63	0.17	1506	1.56	1.60
3	0558	0.332	2.08	0.58	1190	5.47	7.08
4	0608	0.292	1.83	0.88	819	3.06	10.14
5	0618	0.235	1.47	1.16	460	1.78	11.92
6	0628	0.203	1.27	1.34	371	0.73	12.66
7	0638	0.146	0.91	1.52	278	0.57	13.24
8	0648	0.134	0.84	1.72	637	0.93	14.17
9	0658	0.227	1.42	1.90	1209	1.64	15.81
10	0708	0.414	2.59	2.15	1609	3.57	19.39
11	0718	0.657	4.11	2.87	1700	11.76	31.16
12	0728	0.851	5.33	3.55	1760	11.86	43.02
13	0738	1.091	6.83	4.59	2300	21.14	64.16
14	0748	1.208	7.57	5.81	2500	29.26	93.42
15	0808	0.941	5.89	8.02	2120	51.04	144.47
16	0831	0.539	3.38	9.72	1550	31.22	175.70
17	0900	0.264	1.65	10.87	600	12.28	187.98
18	0925	0.166	1.04	11.45	380	2.86	190.85
19	1004	0.097	0.61	11.96	100	1.21	192.07
20	1053	0.057	0.36	12.31	100	0.35	192.42
21	2400	0.002	0.01	13.20	100	0.88	193.31
22	1520 (24 May)	0.000	0.00	13.56	100	0.35	193.67

TABLE F-3. SEDIMENT LOST BY RUNOFF FROM EVENT OF 27 MAY, 1977

Rainfall: 22.35 mm Runoff: 1.85 mm
Sediment/Runoff Ratio: 3.75 kg/ha/mm

Sample No.	Time	Runoff Rate m^3/s	Runoff Rate mm/h	Accum. Runoff mm	Sed. Load in Sample mg/l	Sed. per Interval kg/ha	Accum. Sed. Loss kg/ha
1	0222	0.032	0.20	0.01	2132	0.27	0.27
2	0242	0.105	0.66	0.04	1315	0.52	0.79
3	0302	0.118	0.74	0.12	802	0.83	1.63
4	0322	0.114	0.71	0.66	261	2.86	4.49
5	0342	0.093	0.58	0.86	316	0.58	5.07
6	0402	0.073	0.46	1.04	238	0.49	5.57
7	0422	0.053	0.33	1.16	223	0.29	5.86
8	0442	0.041	0.25	1.27	196	0.21	6.07
9	0502	0.028	0.18	1.34	217	0.15	6.23
10	2200	0.000	0.00	1.85	68	0.72	6.95

TABLE F-4. SEDIMENT LOST BY RUNOFF FROM EVENT OF 1 JULY, 1977

Rainfall: 45.72 mm Runoff: 1.72 mm
Sediment/Runoff Ratio: 18.68 kg/ha/mm

Sample No.	Time	Runoff Rate m^3/s	Runoff Rate mm/h	Accum. Runoff mm	Sed. Load in Sample mg/l	Sed. per Interval kg/ha	Accum. Sed. Loss kg/ha
1	0502	0.288	1.80	0.14	1760	2.01	2.01
2	0523	0.304	1.90	0.84	2515	15.58	17.59
3	0543	0.114	0.71	1.27	1841	9.29	26.88
4	0602	0.061	0.38	1.39	1322	2.00	28.89
5	0622	0.028	0.18	1.52	1153	1.57	30.46
6	0643	0.016	0.10	1.57	889	0.51	30.98
7	0703	0.012	0.08	1.60	853	0.22	31.20
8	0723	0.008	0.05	1.62	734	0.20	31.40
9	1400	0.000	0.00	1.71	734	0.67	32.08

TABLE F-5. SEDIMENT LOST BY RUNOFF FROM EVENT OF 14 NOVEMBER, 1978

Rainfall: 47.75 mm Runoff: 0.94 mm
Sediment/Runoff Ratio: 7.30 kg/ha/mm

Sample No.	Time	Runoff Rate m^3/s	Runoff Rate mm/h	Accum. Runoff mm	Sed. Load in Sample mg/l	Sed. per Interval kg/ha	Accum. Sed. Loss kg/ha
1	1923	0.006	0.04	0.00	562	0.01	0.01
2	1936	0.089	0.56	0.06	865	0.45	0.46
3	1947	0.109	0.69	0.18	813	0.95	1.42
4	1956	0.105	0.66	0.28	807	0.84	2.27
5	2006	0.085	0.53	0.38	866	0.85	3.12
6	2016	0.069	0.43	0.45	885	0.62	3.74
7	2026	0.057	0.36	0.53	807	0.64	4.38
8	2036	0.049	0.30	0.58	787	0.40	4.79
9	2045	0.041	0.25	0.63	729	0.38	5.17
10	2055	0.028	0.18	0.66	657	0.17	5.35
11	2105	0.024	0.15	0.70	662	0.30	5.65
12	2115	0.020	0.13	0.71	595	0.03	5.68
13	2125	0.016	0.10	0.73	642	0.15	5.84
14	2135	0.012	0.08	0.76	579	0.15	5.99
15	2146	0.012	0.07	0.77	586	0.04	6.04
16	2157	0.010	0.06	0.78	621	0.07	6.12
17	2209	0.009	0.05	0.79	513	0.05	6.17
18	2221	0.007	0.05	0.80	545	0.05	6.23
19	0820 (15 Nov)	0.000	0.00	0.94	370	0.62	6.85

TABLE F-6. SEDIMENT LOST BY RUNOFF FROM EVENT OF 18 MARCH, 1979

Rainfall: 20.32 mm Runoff: 0.56 mm
Sediment/Runoff Ratio: 21.21 kg/ha/mm

Sample No.	Time	Runoff Rate m^3/s	Runoff Rate mm/h	Accum. Runoff mm	Sed. Load in Sample mg/l	Sed. per Interval kg/ha	Accum. Sed. Loss kg/ha
1	1101	0.016	0.10	0.00	1828	0.09	0.09
2	1133	0.028	0.18	0.07	3760	1.98	2.08
3	1213	0.020	0.13	0.30	1984	6.56	8.64
4	1318	0.008	0.05	0.48	1332	2.94	11.59
5	1430	0.002	0.01	0.50	980	0.29	11.88
6	1548	0.001	0.01	0.31	736	1.63	10.25
7	1843	0.000	0.00	0.53	616	1.45	11.71
8	2200	0.000	0.00	0.55	508	0.14	11.85

TABLE F-7. SEDIMENT LOST BY RUNOFF FROM EVENT OF 22 MARCH, 1979

Rainfall: 55.37 mm Runoff: 16.43 mm
Sediment/Runoff Ratio: 25.03 kg/ha/mm

Sample No.	Time	Runoff Rate m^3/s	Runoff Rate mm/h	Accum. Runoff mm	Sed. Load in Sample mg/l	Sed. per Interval kg/ha	Accum. Sed. Loss kg/ha
1	0528	0.146	0.91	0.07	1104	0.84	0.84
2	0546	0.304	1.90	0.55	3469	11.03	11.87
3	0606	0.539	3.38	1.44	2808	27.90	39.77
4	0637	0.896	5.61	3.75	3788	76.23	116.00
5	0710	1.220	7.65	7.06	3828	125.74	241.74
6	0737	0.766	4.80	10.26	2544	101.96	343.71
7	0813	0.430	2.69	12.49	1429	44.40	388.11
8	0839	0.308	1.93	13.51	758	11.10	399.21
9	1430	0.008	0.05	15.69	236	10.83	410.04
10	1400 (23 March)	0.000	0.00	16.43	108	1.26	411.31

TABLE F-8. SEDIMENT LOST BY RUNOFF FROM EVENT OF 10 APRIL, 1979

Rainfall: 26.92 mm Runoff: 1.85 mm
Sediment/Runoff Ratio: 18.70 kg/ha/mm

Sample No.	Time	Runoff Rate m^3/s	Runoff Rate mm/h	Accum. Runoff mm	Sed. Load in Sample mg/l	Sed. per Interval kg/ha	Accum. Sed. Loss kg/ha
1	1822	0.211	1.32	0.10	2302	2.33	2.33
2	1836	0.264	1.65	0.48	2420	8.99	11.33
3	1840	0.243	1.52	0.58	3260	2.88	14.22
4	1854	0.170	1.07	0.88	2307	8.48	22.70
5	1906	0.126	0.79	1.06	2134	3.94	26.65
6	1914	0.105	0.66	1.16	1852	2.02	28.67
7	1924	0.081	0.51	1.27	1546	1.72	30.40
8	1934	0.061	0.38	1.34	1159	1.03	31.43
9	1945	0.049	0.30	1.39	1045	0.56	31.99
10	1952	0.045	0.28	1.44	990	0.51	32.51
11	2000	0.041	0.25	1.47	876	0.23	32.74
12	2008	0.036	0.23	1.49	714	0.20	32.94
13	2016	0.028	0.18	1.52	648	0.17	33.12
14	2024	0.024	0.15	1.54	682	0.16	33.29
15	2032	0.024	0.15	1.57	631	0.16	33.45
16	2040	0.020	0.13	1.60	596	0.15	33.61
17	2056	0.016	0.10	1.62	547	0.14	33.75
18	2105	0.016	0.10	1.64	492	0.09	33.85
19	2113	0.012	0.08	1.65	462	0.06	33.91
20	2122	0.012	0.08	1.66	457	0.05	33.97
21	2135	0.010	0.06	1.68	438	0.06	34.03
22	2152	0.009	0.05	1.70	378	0.07	34.11
23	2208	0.008	0.05	1.71	438	0.05	34.16
24	2230	0.006	0.04	1.73	361	0.06	34.22
25	1600 (11 April)	0.000	0.00	1.85	361	0.44	34.67

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TABLE F-9. SEDIMENT LOST BY RUNOFF FROM EVENT OF 2-3 MAY, 1979

Rainfall: 99.31 mm Runoff: 32.03 mm
Sediment/Runoff Ratio: 10.55 kg/ha/mm

Sample No.	Time	Runoff Rate m^3/s	Runoff Rate mm/h	Accum. Runoff mm	Sed. Load in Sample mg/l	Sed. per Interval kg/ha	Accum. Sed. Loss kg/ha
1	0904	0.105	0.66	0.07	1482	1.12	1.12
2	0914	0.138	0.86	0.20	2058	2.24	3.37
3	0924	0.134	0.84	0.35	2253	3.28	6.66
4	0932	0.122	0.76	0.45	2032	2.17	8.83
5	0954	0.093	0.58	0.71	1248	4.16	13.00
6	1017	0.077	0.48	0.88	721	1.75	14.75
7	1047	0.065	0.41	1.11	501	1.39	16.15
8	1112	0.073	0.46	1.29	415	0.81	16.96
9	1152	0.065	0.41	1.60	254	1.02	17.98
10	2034	1.707	10.69	4.19	1967	28.77	46.75
11	2038	1.808	11.33	4.92	5484	27.44	74.19
12	2050	1.480	9.27	6.98	5167	109.56	183.76
13	2057	1.168	7.32	7.95	3239	40.56	224.33
14	2110	0.722	4.52	9.24	2242	35.50	259.83
15	2120	0.539	3.38	9.90	1556	12.54	272.37
16	2134	0.373	2.34	10.59	1337	9.92	282.29
17	2152	0.264	1.65	11.17	796	6.23	288.52
18	2207	0.203	1.27	11.53	520	2.34	290.86
19	2222	0.162	1.02	11.81	721	1.73	292.59
20	2252	0.097	0.61	12.19	319	1.98	294.57
21	2254 (2 May)	0.093	0.58	12.24	280	0.15	294.73

(Continued)

TABLE F-9. (Continued)

Rainfall: 99.31 mm Runoff: 32.03 mm
Sediment/Runoff Ratio: 10.55 kg/ha/mm

Sample No.	Time	Runoff Rate m^3/s	Runoff Rate mm/h	Accum. Runoff mm	Sed. Load in Sample mg/l	Sed. per Interval kg/ha	Accum. Sed. Loss kg/ha
22	1345	0.053	0.33	14.19	61	3.33	298.06
23	1544	0.158	0.99	15.51	293	2.33	300.40
24	1552	0.219	1.37	15.67	412	0.53	300.94
25	1600	0.251	1.57	15.87	482	0.90	301.84
26	1608	0.284	1.78	16.07	488	0.98	302.83
27	1616	0.304	1.90	16.33	580	1.35	304.19
28	1623	0.308	1.93	16.56	593	1.34	305.53
29	1630	0.304	1.90	16.78	546	1.30	306.83
30	1638	0.284	1.78	17.01	462	1.15	307.98
31	1647	0.268	1.68	17.29	432	1.24	309.23
32	1654	0.243	1.52	17.47	397	0.73	309.97
33	1702	0.219	1.37	17.67	352	0.76	310.73
34	1710	0.195	1.22	17.83	317	0.51	311.24
35	1718	0.178	1.12	17.98	328	0.49	311.73
36	1726	0.158	0.99	18.13	318	0.49	312.22
37	1732	0.146	0.91	18.23	306	0.31	312.54
38	1741	0.130	0.81	18.36	249	0.35	312.89
39	1749	0.122	0.76	18.46	259	0.25	313.15
40	1757	0.118	0.74	18.56	249	0.25	313.40
41	1805	0.109	0.69	18.66	205	0.23	313.64
42	1812	0.109	0.69	18.74	240	0.17	313.80
43	1819	0.109	0.69	18.82	232	0.18	313.98
44	1826	0.122	0.75	18.89	228	0.17	314.16
45	1834	0.138	0.86	19.02	224	0.28	314.45
46	1842 (3 May)	0.166	1.04	19.15	210	0.27	314.72
47	1730 (7 May)	0.000	0.00	32.02	150	23.18	337.90

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TABLE F-10. SEDIMENT LOST BY RUNOFF FROM EVENT OF 9 JUNE, 1979

Rainfall: 75.95 mm Runoff: 8.76 mm
Sediment/Runoff Ratio: 14.38 kg/ha/mm

Sample No.	Time	Runoff Rate m^3/s	Runoff Rate mm/h	Accum. Runoff mm	Sed. Load in Sample mg/l	Sed. per Interval kg/ha	Accum. Sed. Loss kg/ha
1	0227	0.896	5.61	0.25	4044	10.27	10.27
2	0237	1.074	6.73	1.17	3341	33.76	44.03
3	0243	0.851	5.33	1.85	2740	20.85	64.88
4	0253	0.633	3.96	2.56	1671	15.69	80.57
5	0301	0.414	2.59	3.28	1215	10.26	90.83
6	0311	0.296	1.85	3.66	930	4.09	94.92
7	0319	0.215	1.35	3.86	832	1.79	96.71
8	0327	0.142	0.89	4.11	707	1.95	98.66
9	0335	0.109	0.69	4.22	514	0.62	99.28
10	0343	0.097	0.61	4.27	548	0.27	99.55
11	0350	0.081	0.51	4.32	472	0.26	99.81
12	0358	0.069	0.43	4.37	452	0.23	100.04
13	0405	0.057	0.36	4.42	406	0.22	100.26
14	0414	0.049	0.30	4.47	375	0.20	100.46
15	0836	0.414	2.59	5.13	440	2.69	103.15
16	0844	0.397	2.49	5.41	1154	2.23	105.38
17	0852	0.385	2.41	5.69	1329	3.47	108.85
18	0900	0.369	2.31	5.99	1043	3.61	112.46
19	0909	0.357	2.24	6.27	782	2.55	115.01
20	0917	0.296	1.85	6.86	586	4.00	119.01
21	0926	0.239	1.50	6.91	532	0.00	119.01
22	0934	0.215	1.35	7.01	424	0.73	119.74
23	0941	0.191	1.19	7.14	350	0.49	120.23
24	0949	0.146	0.91	7.54	366	1.45	121.68
25	1502	0.000	0.00	8.76	350	4.36	126.04

TABLE F-11. SEDIMENT LOST BY RUNOFF FROM EVENT OF 5 JULY, 1979

Rainfall: 52.07 mm Runoff: 2.36 mm
Sediment/Runoff Ratio: 10.98 kg/ha/mm

Sample No.	Time	Runoff Rate m^3/s	Runoff Rate mm/h	Accum. Runoff mm	Sed. Load in Sample mg/l	Sed. per Interval kg/ha	Accum. Sed. Loss kg/ha
1	2224	0.187	1.17	0.14	2355	3.35	3.35
2	2234	0.187	1.17	0.35	2310	4.97	8.32
3	2243	0.158	0.99	0.50	1981	3.27	11.59
4	2249	0.130	0.81	0.58	1622	1.37	12.96
5	2257	0.097	0.61	0.68	1506	1.58	14.55
6	2305	0.081	0.51	0.76	1342	1.08	15.64
7	2314	0.069	0.43	0.83	1238	0.98	16.62
8	2322	0.061	0.38	0.88	1100	0.59	17.22
9	2330	0.053	0.33	0.94	1001	0.53	17.75
10	1820 (7 July)	0.000	0.00	2.36	150	8.18	25.93

TABLE F-12. SEDIMENT LOST BY RUNOFF FROM EVENT OF 17 JULY, 1979

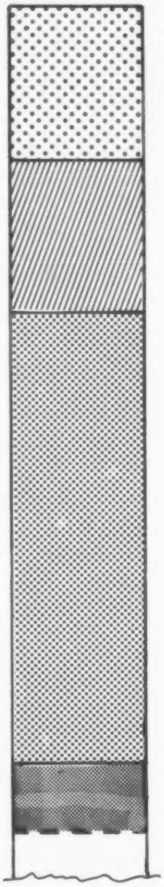
Rainfall: 82.55 mm Runoff: 23.47 mm
Sediment/Runoff Ratio: 31.43 kg/ha/mm

Sample No.	Time	Runoff Rate m^3/s	Runoff Rate mm/h	Accum. Runoff mm	Sed. Load in Sample mg/l	Sed. per Interval kg/ha	Accum. Sed. Loss kg/ha
1	0332	2.749	17.22	1.70	8604	146.42	146.42
2	0338	4.395	27.53	4.08	5422	167.44	313.86
3	0346	4.634	29.03	7.95	2800	158.71	472.58
4	0356	3.463	21.69	12.11	2586	112.18	584.76
5	0403	2.494	15.62	14.30	2188	52.14	636.90
6	0411	1.638	10.26	16.02	2024	36.37	673.27
7	0418	1.143	7.16	17.04	1732	19.08	692.35
8	0424	0.896	5.61	17.67	1515	10.30	702.66
9	0433	0.685	4.29	18.41	1140	9.77	712.44
10	0441	0.539	3.38	18.92	1019	5.48	717.92
11	0448	0.458	2.87	19.30	838	3.53	721.46
12	0456	0.373	2.34	19.63	715	2.56	724.03
13	0503	0.332	2.08	19.91	644	1.89	725.92
14	0512	0.304	1.90	20.21	571	1.85	727.78
15	0520	0.268	1.68	20.44	542	1.27	729.05
16	0527	0.251	1.57	20.62	453	0.88	729.93
17	0534	0.231	1.45	20.82	442	0.90	730.84
18	0541	0.211	1.32	20.98	416	0.65	731.50
19	0549	0.195	1.22	21.15	357	0.68	732.18
20	0556	0.178	1.12	21.28	372	0.46	732.65
21	0602	0.162	1.02	21.38	336	0.36	733.01
22	0611	0.146	0.91	21.53	314	0.49	733.50
23	0619	0.134	0.84	21.64	276	0.30	733.80
24	0626	0.122	0.76	21.74	255	0.27	734.07
25	1930 (19 July)	0.000	0.00	23.47	159	3.57	737.64

APPENDIX G

SOIL PROFILE DESCRIPTIONS OF SAMPLING LOCATIONS

Location No. 1



A 1 -- 0 - 23 cm - Very dark grayish brown (10YR 3/2) moist; loam; weak medium subangular blocky breaking to weak fine granular structure; friable when moist; common medium size roots; gradual boundary.

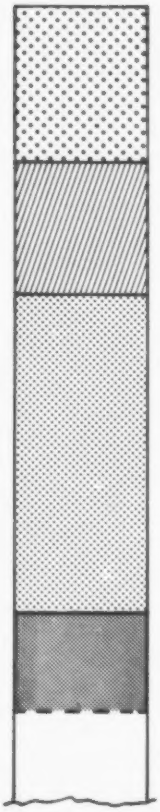
B21t -- 23 - 46 cm - Dark brown (7.5YR 3/3 moist; loam; moderate medium subangular blocky breaking to granular structure; friable when moist; few fine iron-manganese oxide bodies; few fine roots; thin patchy clay films; gradual boundary.

B22t -- 46 - 114 cm - Brown (7.5YR 4/4) clay loam; common fine distinct reddish brown (5YR 4/4) mottles; moderate medium subangular breaking to fine subangular blocky structure; firm when moist; few fine iron-manganese bodies; few fine roots; clay films on ped surfaces.

Cr -- 114+ cm.

Stoneburg soils.

Location No. 2



A1 -- 0 - 23 cm - Dark reddish brown (5YR 3/3) moist; loam; weak medium subangular blocky breaking to weak medium granular structure; friable when moist; common medium roots; clear boundary.

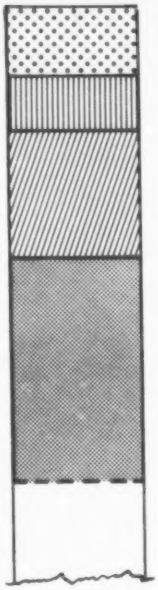
II B21t -- 23 - 43 cm - Dark reddish brown (2.5YR 3/4) moist silty clay; moderate coarse subangular breaking to moderate fine and medium blocky structure; firm when moist; few fine roots; few iron-manganese oxide bodies; few clay films; diffuse boundary.

II B22t -- 43 - 106 cm - Dark red (2.5YR 3/6) moist silty clay; weak coarse blocky breaking to weak fine blocky structure; firm when moist; few fine roots; few iron-manganese oxide bodies; ped faces are shiny with clay films.

Cr -- 106+ cm.

Grainola soils

Location No. 3



A1 -- 0 - 10 cm - Dark brown (7.5YR 3/2) moist; loam; moderate coarse granular structire; friable when moist; common coarse and medium roots; clear boundary.

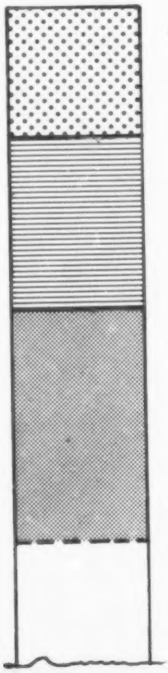
B1 -- 10 - 18 cm - Dark brown (7.5YR 3/3) moist; loam moderate medium subangular blocky breaking to granular structure; friable when moist; few fine roots; clear boundary.

B21t -- 18 - 37 cm - Dark reddish brown (5YR 3/3) moist; clay loam (30% clay estimate); weak coarse subangular blocky structure breaking to fine subangular structure; firm grading to friable when moist; few fine roots; few fine manganese-iron oxide bodies; few thin clay films on ped surfaces; clear boundary.

B3 and Cr -- 37 - 71 cm - Alternating thin layers of reddish brown (5YR 4/5) loam, B3 and soft sandstone Cr, ranging in colors from red to reddish yellow to very pale brown.

Stoneburg soils.

Location No. 4



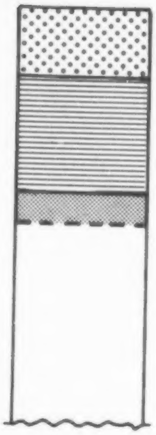
A1 -- 0 - 19 cm - Brown (7.5YR 4/3) moist; fine sandy loam; weak fine granular structure; very friable when moist; common coarse roots; clear boundary.

B2t -- 19 - 45 cm - Reddish brown (5YR 4/4) moist; loam; weak coarse subangular blocky breaking to granular structure; friable when moist; few fine and medium roots; thin patchy clay films; clear boundary.

Cr -- 45 - 80 cm - Soft sandstone ranging in color from pale brown to brownish yellow; few fine roots.

Darnell-like soils with minimal argillic horizon development.

Location No. 5



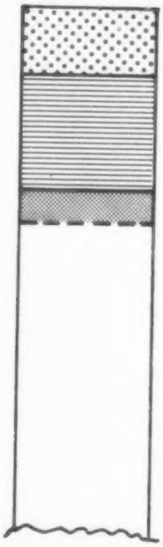
A1 -- 0 - 10 cm - Dark brown (10YR 3/3) moist; fine sandy loam; weak fine granular structure; very friable when moist; common coarse roots; clear boundary.

B2 -- 10 - 27 cm - Brown (7.5YR 4/4) moist; fine sandy loam; weak coarse subangular blocky breaking to granular structure; few fine and medium roots; clear boundary.

Cr -- 27 - 32 cm - Light yellowish brown (10YR 6/4) moist soft sandstone.

Darnell soils.

Location No. 6



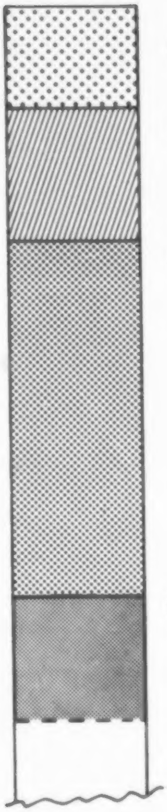
A1 -- 0 - 10 cm - Very dark grayish brown (10YR 3/2) moist; fine sandy loam; weak fine granular structure; very friable when moist; common coarse and medium roots; clear boundary.

B2 -- 10 - 27 cm - Brown (7.5YR 4/4) moist; fine sandy loam; weak coarse subangular blocky breaking to granular structure; few fine and medium roots; clear boundary.

Cr -- 27 - 32 cm - Light yellowish brown (10YR 6/4) moist soft sandstone.

Darnell soils.

Location No. 7



A1 -- 0 - 15 cm - Dark brown (7.5YR 3/3) moist; loam; weak medium subangular breaking to moderate medium granular structure; friable when moist; common coarse roots; gradual boundary.

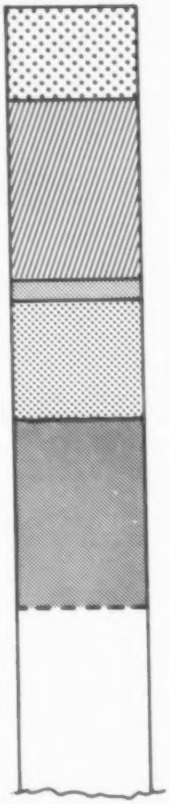
B21t -- 15 - 35 cm - Brown (7.5YR 4/4) moist; clay loam; weak medium subangular structure; firm when moist; few fine roots; clay films on ped surfaces; clear boundary.

B22t -- 35 - 88 cm - Yellowish brown (10YR 5/4) moist; clay loam; few fine point brown mottles; weak coarse subangular structure; firm when moist; few fine roots; few fine iron-manganese oxide bodies; clay films on ped surfaces.

Cr -- 88+ cm.

Soils are gradational between Stoneburg and Grainola soils with less than normal solum thickness.

Location No. 8



A1 -- 0 - 14 cm - Dark brown (10YR 3/3) moist; loam; weak medium subangular breaking to weak medium granular structure; friable when moist; common coarse roots; clear boundary.

B21t -- 14 - 41 cm - Brown (7.5YR 4/4) clay loam moderate medium subangular blocky breaking to fine subangular blocky structure; firm when moist; few fine roots; few fine iron-manganese oxide bodies; clay films on ped surface; abrupt boundary.

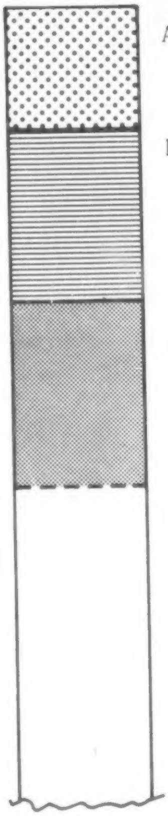
Cr -- 41 - 44 cm - Thin layers of yellow and very pale brown sandy shale; abrupt boundary.

II B22t -- 44 - 62 cm - Light brownish gray (10YR 6/2) moist; clay loam high in sand; weak coarse subangular blocky structure; firm when moist; few fine roots; common coarse bodies of brown (7.5YR 4/4) moist clay loam; clay films on ped surfaces few fine iron-manganese oxide concretion.

Cr -- 62+ cm.

Zaneis-like soils. No mollic epipedon.

Location No. 9



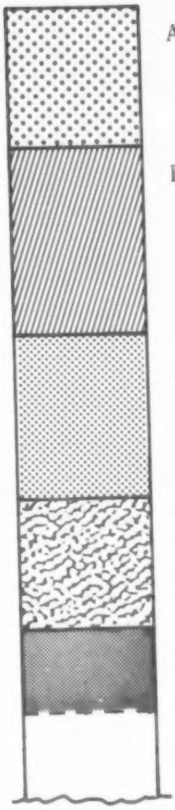
A1 -- 0 - 18 cm - Dark brown (10YR 3/3) moist; loam; weak medium subangular breaking to weak medium granular structure; friable when moist; common medium roots; clear boundary.

B2t -- 18 - 44 cm - Dark yellowish brown (10YR 4/4) moist; clay loam; weak medium subangular blocky structure; firm when moist; few fine roots; clay films on ped surfaces; clear boundary.

Cr -- 44 - 72 cm - Very pale brown (10YR 7/4) moist soft sandstone.

Stoneburg-like soils with less than normal thickness.

Location No. 10



A1 -- 0 - 21 cm - Very dark grayish brown (10YR 3/2) moist; loam; weak coarse subangular blocky breaking to granular structure; friable when moist; common coarse roots; clear boundary.

B21t -- 21 - 49 cm - Dark reddish brown (5YR 3/4) moist; loam; weak medium subangular blocky structure breaking to granular structure; friable when moist; few fine roots; clay films on ped surfaces; gradual boundary.

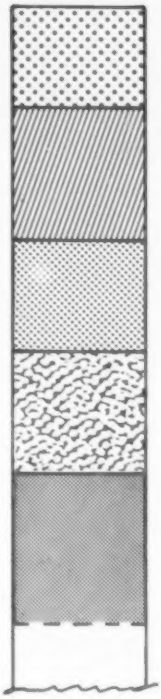
B22t -- 49 - 74 cm - Dark reddish brown (5YR 3/4) moist; clay loam; moderate medium subangular blocky structure; firm when moist; few fine roots; few fine iron-manganese oxide bodies; clay films on ped surface; clear boundary.

II B3t -- 74 - 94 cm - Light brownish gray (10YR 6/2) clay loam; weak fine blocky structure; firm when moist; few fine roots; clay films on ped surfaces.

Cr -- 94+ cm.

Stoneburg-like soils.

Location No. 11



A1 -- 0 - 15 cm - Dark brown (7.5YR 3/3) moist; loam; weak medium granular structure; friable when moist; common medium roots; gradual boundary.

B21 -- 15 - 35 cm - Brown (7.5YR 4/4) moist; loam; weak coarse subangular blocky breaking to granular structure; friable when moist; few fine roots; clear boundary.

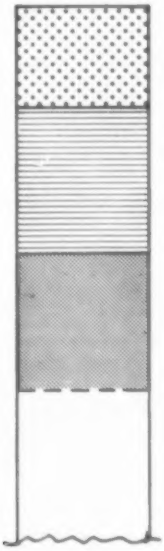
B22 -- 35 - 52 cm - Dark yellowish brown (10YR 4/4) moist; loam; weak coarse subangular blocky breaking to granular structure; friable when moist; few fine roots; clear boundary.

B3 -- 52 - 70 cm- Coarsely mottled dark grayish brown (10YR 4/2) moist and pale brown (10YR 6/3) moist; loam; weak coarse subangular blocky structure; friable when moist; few fine roots.

Cr -- 70+ cm.

Noble-like soils.

Location No. 12



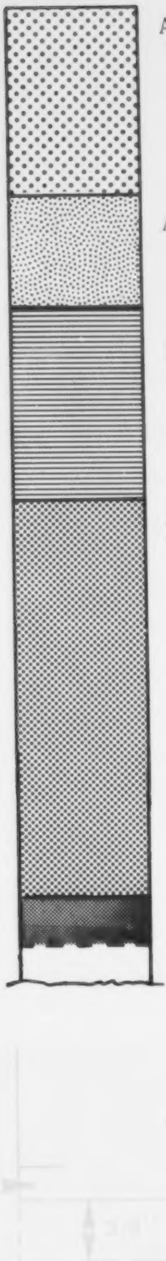
A1 -- 0 - 15 cm - Dark brown (7.5YR 3/3) moist; loam; weak coarse subangular blocky breaking to moderate fine granular structure; friable when moist; common medium roots; clear boundary.

B2 -- 15 - 37 cm - Brown (7.5YR 4/3) moist;loam; weak coarse subangular blocky breaking to granular structure; friable when moist; few fine roots.

Cr -- 37+ cm.

Lucien soils.

Location No. 13



A1 -- 0 - 28 - Dark brown (7.5YR 3/3) moist; loam; weak coarse subangular blocky breaking to moderate fine granular structure; friable; common medium roots; gradual boundary.

A3 -- 28 - 45 cm - Dark reddish brown (5YR 3/3) moist; loam; weak medium subangular blocky breaking to moderate medium granular studcture; friable when moist; common medium roots; gradual boundary.

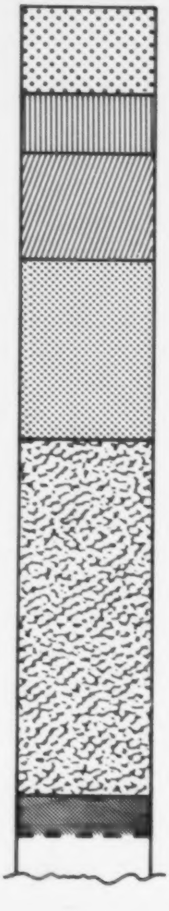
B2t -- 45 - 74 cm - Reddish brown (5YR 4/4) loam; weak medium subangular blocky structure; friable grading to firm when moist; few fine roots; clay films on ped surfaces; clear boundary.

B22t -- 74 - 134 cm - Coarsely mottled reddish brown (5YR 5/3) (5YR 5/4) moist to pale brown (10YR 6/3) moist; loam; firm when moist; few fine roots; clay films on ped surfaces.

Cr -- 134+ cm.

Stoneburg soils.

Location No. 14



A1 -- 0 - 13 cm - Dark brown (7.5YR 3/3) moist; silt loam; weak medium subangular blocky breaking to weak medium granular structure; friable when moist; common medium roots; clear boundary.

B1t -- 13 - 22 cm - Dark reddish brown (5YR 3/4) moist; silty clay loam; moderate medium subangular blocky breaking to fine subangular and angular blocky structure; firm when moist; common medium roots; clay films on ped surface; gradual boundary.

B21t -- 22 - 38 cm Dark reddish brown (2.5YR 3/4) moist; silty clay; weak coarse blocky breaking to fine blocky structure; firm when moist; few fine roots; few fine iron-manganese oxide bodies; clay films on ped surfaces; diffuse boundary.

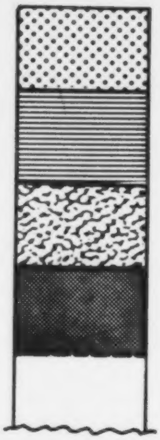
B22t -- 38 - 65 cm - Dark reddish brown (2.5YR 3/4) moist; silty clay; weak coarse blocky breaking to fine blocky structure; very firm when moist; few fine roots; estimated 3 percent calcium carbonate bodies; ped surfaces are shiny; diffuse boundary.

B23t -- 65 - 119 cm - Dark reddish brown (2.5YR 3/4) moist; silty clay; weak coarse blocky breaking to fine blocky structure; very firm when moist; non-intersecting slickensides; few fine roots; shiny ped surfaces.

Cr -- 119+ cm.

Aydelotte soils.

Location No. 15



A-1 -- 0 - 12 cm - Reddish brown (5YR 4/4) moist; loam; weak coarse subangular breaking to weak fine granular structure; friable when moist; common medium roots; clear boundary.

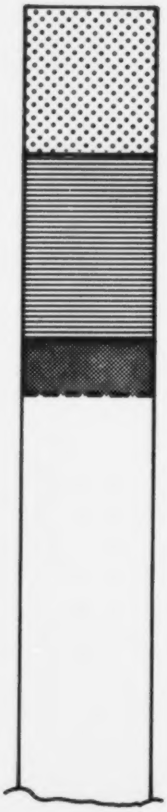
B2t -- 12 26 cm - Reddish brown (5YR 3.5/4) moist; loam; weak medium subangular blocky structure; friable when moist; few fine roots; clay films on ped surfaces; clear boundary.

B3 -- 26 - 39 cm - Brown (7.5YR 4/3) moist loam; weak coarse subangular blocky breaking to granular structure; friable when moist; few fine roots; few fragments of soft sandstone clear boundary.

Cr -- 39 - 52 cm - Light gray (10YR 7/1) moist, soft sandstone.

These soils are gradational in development between Lucien and Stoneburg.

Location No. 16



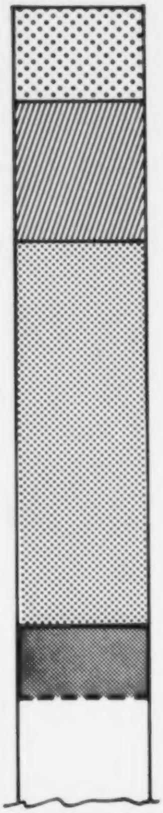
A1 -- 0 - 22 cm - Dark reddish brown (5YR 3/3) moist; loam; weak fine granular structure; common medium roots; gradual boundary.

B2 -- 22-50 cm - Reddish brown (5YR 4/4) moist; loam; weak coarse subangular breaking to granular structure; friable when moist; common medium roots; abrupt boundary.

Cr -- 50 - 58 cm - Very pale brown (10YR 7/3) moist soft sandstone.

Lucien soils.

Location No. 17



A1 -- 0 - 14 cm - Dark brown (10YR 3/3) moist; loam; weak medium subangular blocky breaking to granular structure; friable when moist; common medium roots; gradual boundary.

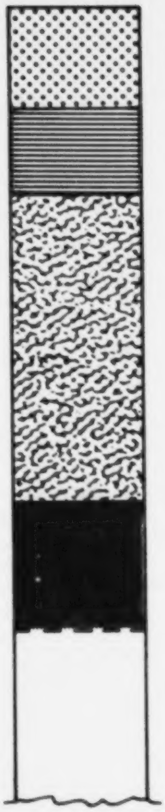
B21t -- 14 - 35 cm - Yellowish brown (10YR 5/4) moist; clay loam; moderate medium subangular blocky breaking to fine subangular blocky structure; few fine and medium roots; clay films on ped surfaces; clear boundary.

B22t -- 35 - 93 cm - Alternating layers of yellow, brown and gray clay and clay loam that average light yellowish brown (10YR 6/4) moist clay; weak medium blocky breaking to fine blocky structure; firm when moist; few fine roots; few thin layers of weathered shale; clay films on ped surfaces; clear boundary.

Cr -- 93 - 114 cm - Dark reddish brown (2.5YR 4/4) moist; shale with few seams of gypsum.

Grainola-like soils.

Location No. 18



A1 -- 0-15 cm - Dark reddish brown (5YR 3/3) moist; loam; weak medium subangular blocky breaking to moderate medium granular structure; friable when moist; common medium roots; gradual boundary.

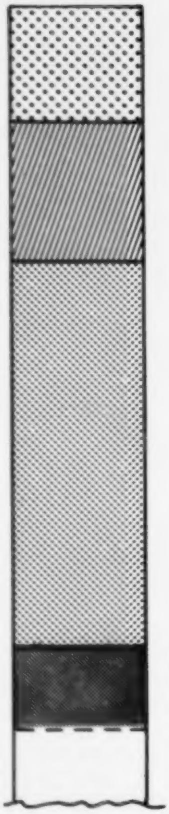
B2 -- 15 28 cm - Reddish brown (5YR 4/3) moist; clay loam; moderate medium subangular blocky structure; moist firm grading to friable; few fine roots; clear boundary.

B3 -- 28 - 75 - Reddish brown (5YR 4/3) moist; clay loam; weak medium subangular blocky breaking to fine subangular blocky structure; firm when moist; common bodies of soft sandstone.

Cr -- 75+ cm.

Gradational soils between Lucien and Grainola.

Location No. 19



A1 -- 0 - 17 cm - Dark reddish brown (5YR 3/3) moist; loam; weak medium subangular blocky breaking to moderate granular structure; friable when moist; common medium roots; gradual boundary.

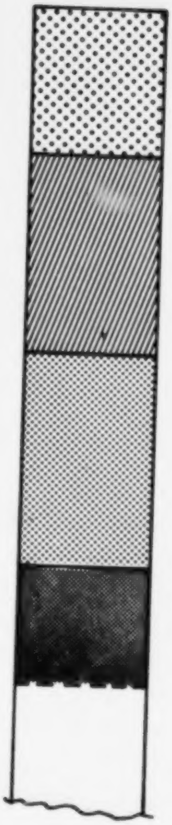
B21t -- 17 - 38 cm - Dark reddish brown (5YR 3/4) moist; clay loam; moderate medium subangular blocky breaking to fine subangular structure; firm when moist grading to friable; common medium and fine roots; clay films on ped surfaces; clear boundary.

B22t -- 38 - 96 cm - Reddish brown (2.5YR 4/4) moist; silty clay; weak medium blocky breaking to fine blocky structure; very fine when moist; few fine roots mostly on ped surfaces; few fine iron-manganese oxide bodies; clay films on ped surfaces.

Cr -- 96+ cm.

Grainola soils.

Location No. 20



A1 -- 0 - 22 cm - Dark brown (10YR 3/3) moist; loam; weak medium granular structure; friable when moist; few fine roots; gradual boundary.

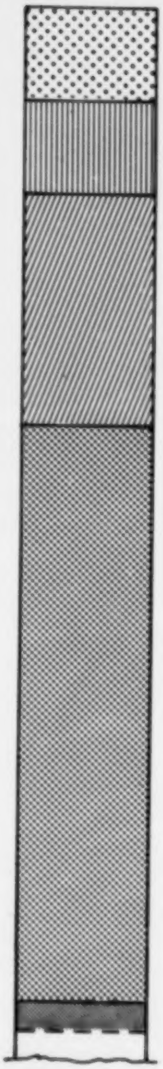
B21t -- 22 - 52 cm - Brown (7.5YR 4/3) moist; clay loam; weak medium subangular blocky structure; firm when moist; few fine roots; clay films on ped surfaces; clear boundary.

B22t -- 52 - 84 cm - Brown (7.5YR 5/4) moist; clay loam; weak coarse blocky breaking to medium blocky structure few fine roots; few fine iron-manganese bodies; clay films on ped surfaces; clear boundary.

Cr -- 84 - 102 cm - Alternating thin layers of very pale brown (10YR 7/3) soft sandstone and light brownish gray (10YR 6/2) shale.

Stoneburg-like soils.

Location No. 21



A1 -- 0 - 14 cm - Dark brown (7.5YR 3/2) moist; silt loam; weak medium subangular blocky breaking to granular structure; friable when moist; common medium roots; gradual boundary.

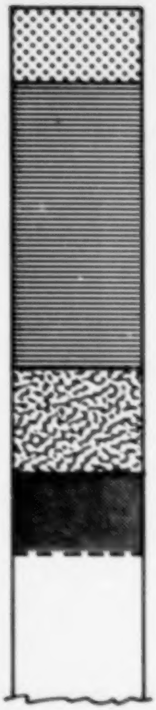
B1t -- 14 - 28 cm - Dark brown (5YR 3/3) moist; silty clay loam; moderate medium subangular blocky breaking to fine subangular blocky structure; friable grading to firm when moist; common medium roots; clay films on ped surface; clear boundary.

B21t -- 28 - 63 cm - Dark reddish brown (5YR 3/4) moist; silty clay; moderate medium blocky breaking to fine blocky structure; firm when moist; few fine roots; clay films on ped surfaces; the lower 10 cm has streaks of olive colored clays; clear boundary.

B22t -- 63 - 150 cm - Dark reddish brown (2.5YR 3/4) moist; silty clay; weak coarse blocky breaking to fine blocky structure; very firm when moist; few fine roots; mostly on ped surfaces; few fine iron-manganese oxides concretions; few non-intersecting slickensides; clay films on ped surfaces.

Cr -- 150+ cm.
Renfrow soils.

Location No. 22



A1 -- 0 - 11 cm - Dark brown (7.5YR 3/3) moist; loam; weak medium granular structure; friable when moist; common medium roots; gradual boundary.

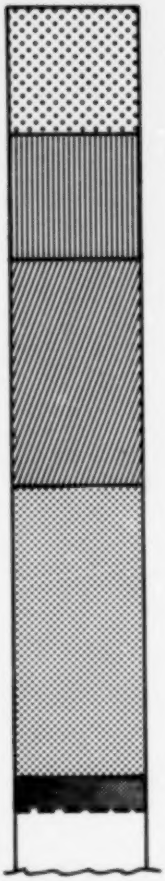
B2t -- 11 - 54 cm - Dark reddish brown (2.5YR 3/4) moist; clay loam; moderate medium subangular blocky breaking to fine subangular blocky structure; firm when moist; few fine roots; clay films on ped surface; clear boundary.

B3 -- 54 - 70 cm - Brown (7.5YR 4/2) moist; clay loam; with common coarse distinct light brownish gray (10YR 6/2) moist mottles; weak coarse subangular blocky structure; firm when moist; few fine roots; clay films on ped surfaces; clear boundary.

Cr -- 70 - 82 cm - Light gray (10YR 7/2) moist soft sandstone.

Stoneburg-like soils.

Location No. 23



A1 -- 0 - 19 cm - Dark brown (7.5YR 3/3) moist; silt loam; weak medium subangular blocky breaking to weak medium granular structure; friable when moist; common coarse and medium roots; gradual boundary.

B1t -- 19 - 38 cm - Dark reddish brown (5YR 3/3) moist; silty clay loam; moderate medium subangular blocky breaking to fine subangular blocky structure; firm grading to friable when moist; common coarse and medium roots; clay films on ped surfaces; clear boundary.

B21t -- 38 - 72 cm - Dark reddish brown (2.5YR 3/4) moist; silty clay; moderate medium subangular blocky breaking to fine blocky structure; firm when moist; few fine roots; few fine iron-manganese oxide bodies; clay films on ped surfaces; gradual boundary.

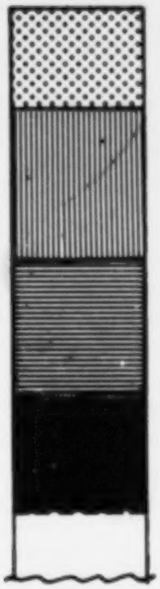
B22t -- 72 - 116 cm - Dark reddish brown (2.5YR 3/4) moist; silty clay; weak coarse blocky breaking to fine blocky structure; very firm when moist; few fine roots; few fine calcium carbonate bodies; few non-intersecting slickensides; clay films on ped surfaces; clear boundary.

Cr -- 116 - 121 cm - Light gray (10YR 6/1) weathered shale with bits of sandstone and silty clay.

Renfrow-like soils with less than normal solum thickness.

TYPING GUIDE SHEET

Location No. 24



A1 -- 0 - 15 cm - Dark reddish brown (5YR 3/2) loam; weak medium subangular blocky breaking to weak medium granular structure; friable when moist; common coarse and medium roots; clear boundary.

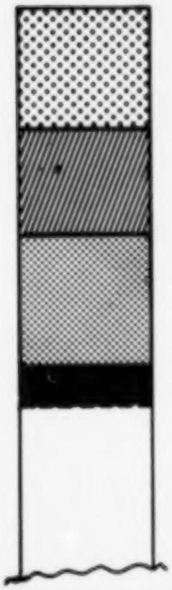
B1t -- 15 - 35 cm - Dark reddish brown (5YR 3/3) moist; clay loam; moderate medium subangular blocky breaking to fine subangular blocky structure; firm grading to friable when moist; few fine and medium roots; clay films on ped surfaces; gradual boundary.

B2t -- 38 - 58 cm - Dark reddish brown (5YR 3/3) moist silty clay; moderate medium subangular blocky breaking to fine blocky structure; firm when moist; few fine medium roots; few fine iron-maganese oxide bodies; clay films on ped surfaces; clear boundary.

Cr -- 58 - 76 cm - Thin layers of very pale brown (10YR 7/3) soft sandstone and light gray (10YR 7/2) shale.

Grainola-like soil with mollic epipedon.

Location No. 25



A1 -- 0 - 18 cm - Dark brown (7.5YR 3/3) moist; loam; moderate medium granular structure; friable when moist; common coarse and medium roots; gradual boundary.

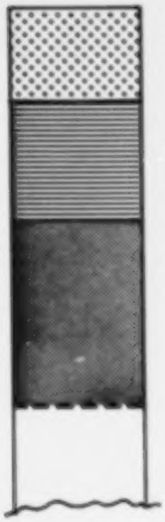
B21t -- 18 - 34 cm - Dark reddish brown (5YR 3/3) moist; clay loam; weak medium subangular blocky breaking to fine subangular blocky structure; firm when moist; common medium roots; clay films on ped surfaces; gradual boundary.

B22t -- 34 - 54 cm - Reddish brown (5YR 5/3) moist clay loam; moderate fine subangular blocky structure; firm when moist; few fine roots; clay films on ped surfaces; clear boundary.

Cr -- 54 - 60 cm - Brown (7.5YR 5/4) moist soft sandstone.

Stoneburg soils.

Location No. 26



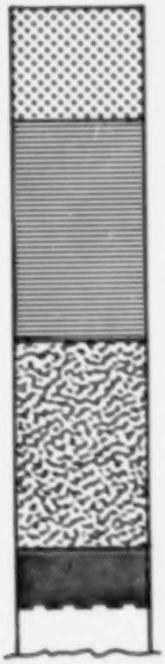
A1 -- 0 - 14 cm - Dark brown (7.5YR 3/3) moist; clay loam; weak medium subangular blocky breaking to moderate medium granular structure; friable grading to firm when moist; common medium roots; gradual boundary.

B2t -- 14 - 32 cm - Reddish brown (5YR 4/3) moist; clay loam; moderate very fine and fine subangular blocky structure; firm when moist; few fine roots; clay films on ped surfaces; clear boundary.

Cr -- 32 - 60 cm - Thin layers reddish brown highly weathered shale; with few seams of light olive brown shale and sandstone; shales texture to clay loam; few fine roots.

Gradational soil development. Grainola-like soils.

Location No. 27



A1 -- 0 - 17 cm - Dark reddish brown (5YR 3/3) moist; loam; weak medium subangular blocky breaking to weak medium granular structure; friable when moist; common medium roots; gradual boundary.

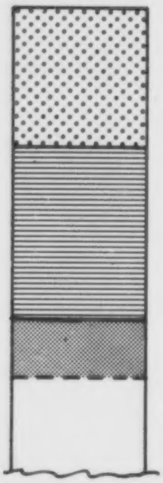
B2t -- 17 - 50 cm - Dark reddish brown (5YR 3/4) moist; clay loam; moderate fine subangular blocky structure; firm grading to friable when moist; common medium and fine roots; clay films on ped surfaces; clear boundary.

B3 -- 50 - 81 cm - Reddish brown (5YR 4/4) clay loam; weak fine subangular blocky structure; firm when moist; few fine roots; common fragments of sandstone.

Cr -- 81+ cm.

Stoneburg-like soils.

Location No. 28



A1 -- 0 - 21 cm - Dark Brown (7.5YR 3/3) moist; loam; weak medium subangular blocky breaking to moderate fine granular structure; friable when moist; common medium roots; gradual boundary.

B2 -- 21 - 47 cm - Brown (7.5YR 4/4) moist; loam; weak medium subangular blocky structure breaking to granular structure; friable when moist; few fine and medium roots; clear boundary.

Cr -- 47 - 56 cm - Olive-yellow (2.5YR 6/6) soft sandstone.

Lucien soils.

Location No. 29

A1 -- 0 - 12 cm - Dark brown (7.5YR 3/3) moist; fine sandy loam; weak fine granular structure; very friable when moist; common medium roots; gradual boundary.

B2 -- 12 - 26 cm - Brown (7.5YR 4/3) moist; fine sandy loam; weak fine granular structure; very friable when moist; few fine roots; clear boundary.

Cr -- 26 - 32 cm - Yellowish brown (10YR 5/4) soft sandstone.

Lucien soils.

APPENDIX H

AVERAGE (21 SAMPLING DATES) SOIL WATER CONTENT (%,$\bar{X}$±SE) FOR SAMPLING LOCATIONS

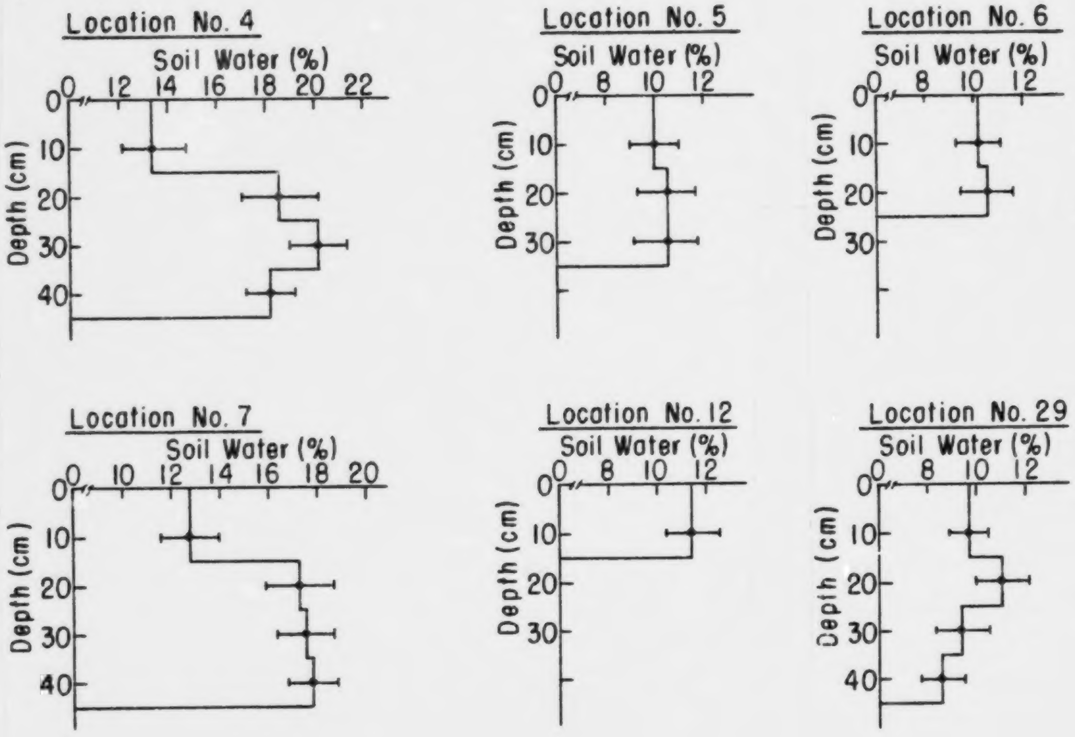


Figure H-1. Soil profiles with depths of 40 cm or less.

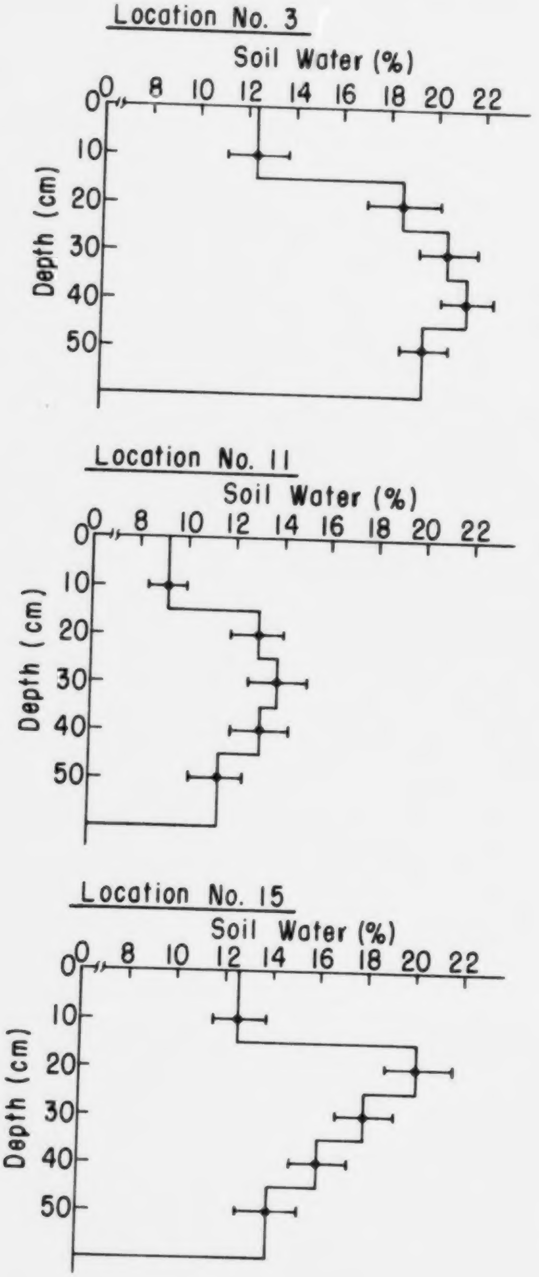


Figure H-2. Soil profiles with depths of 50 cm.

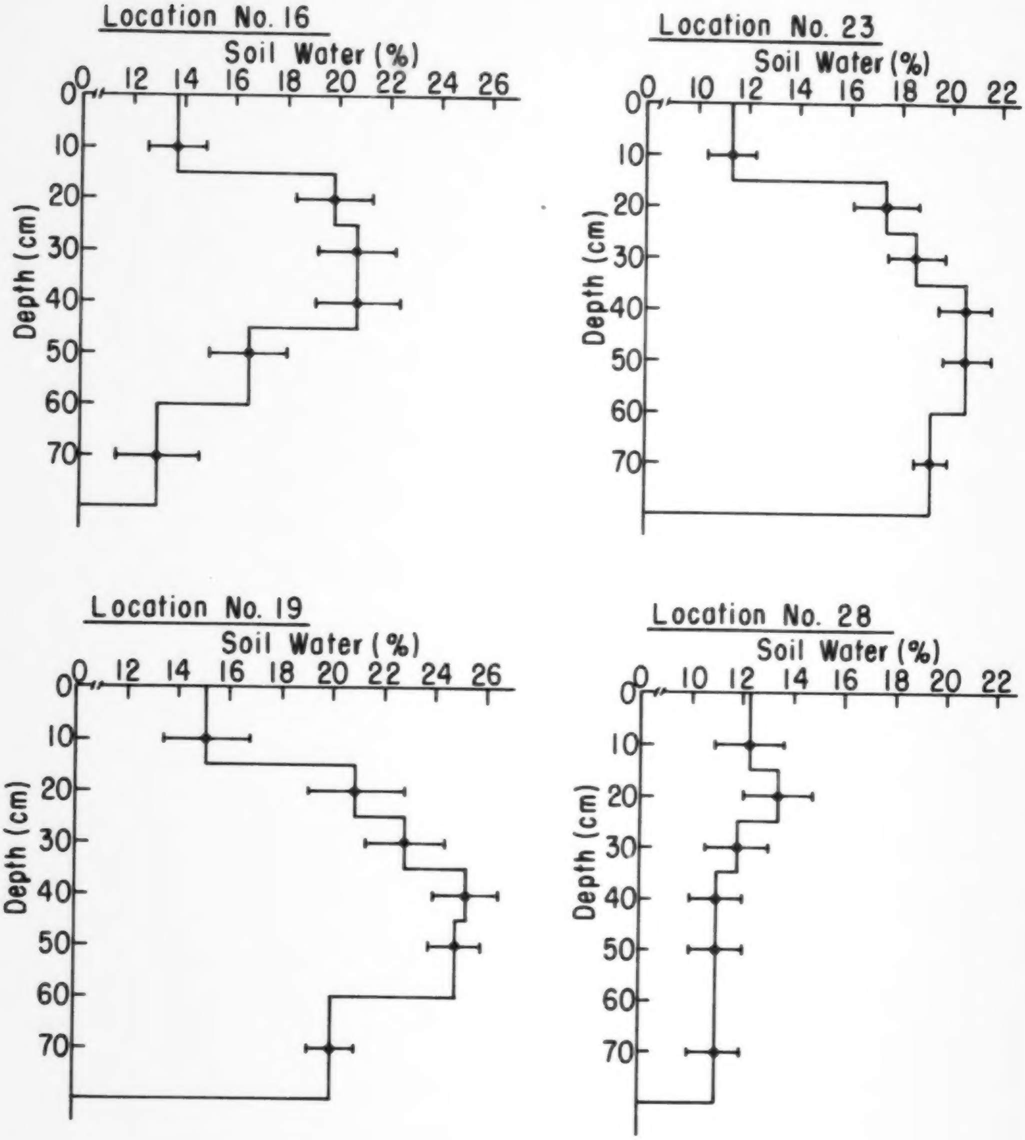


Figure H-3. Soil profiles with depths of of 70 cm.

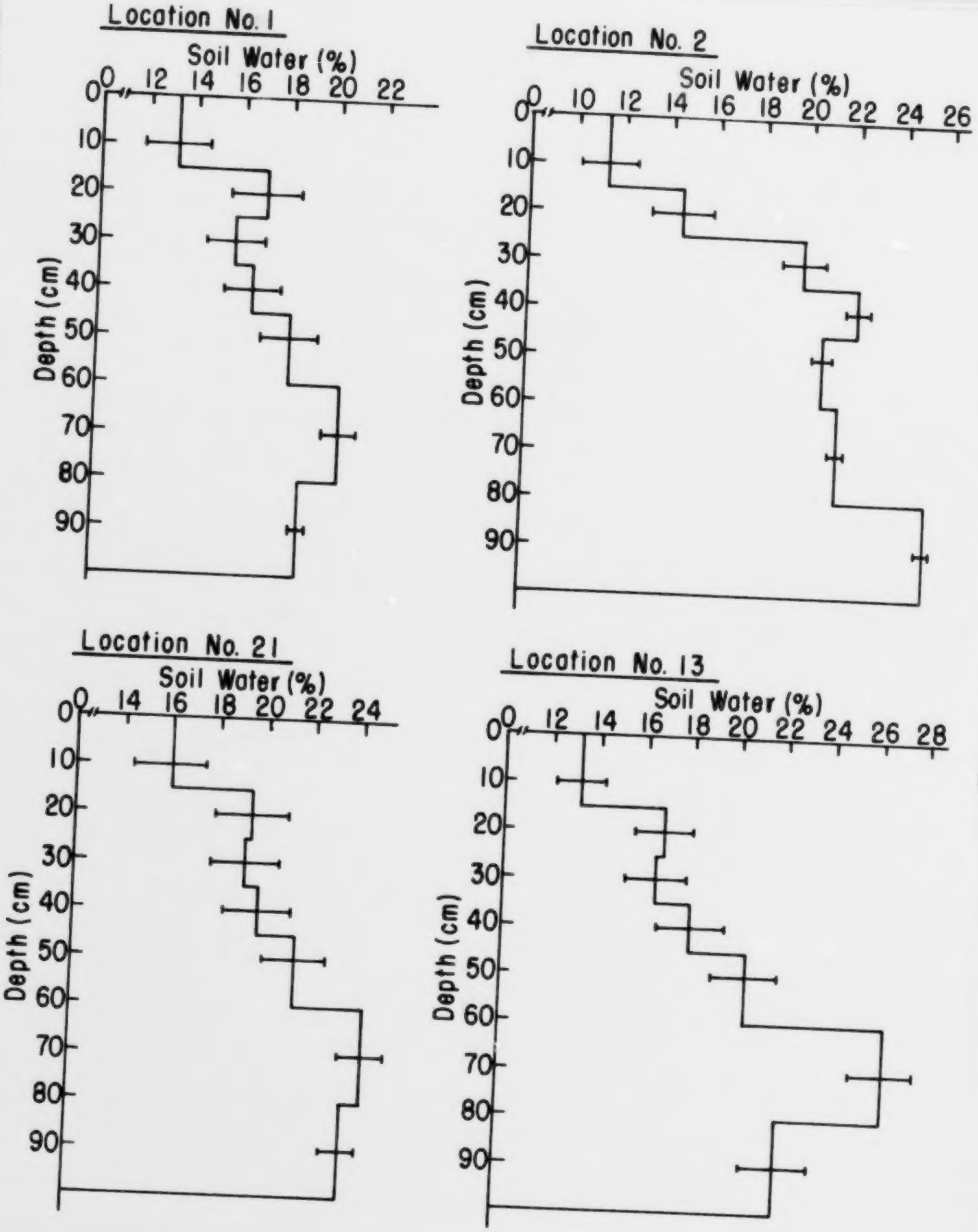


Figure H-4. Soil profiles with depths of 90 cm.

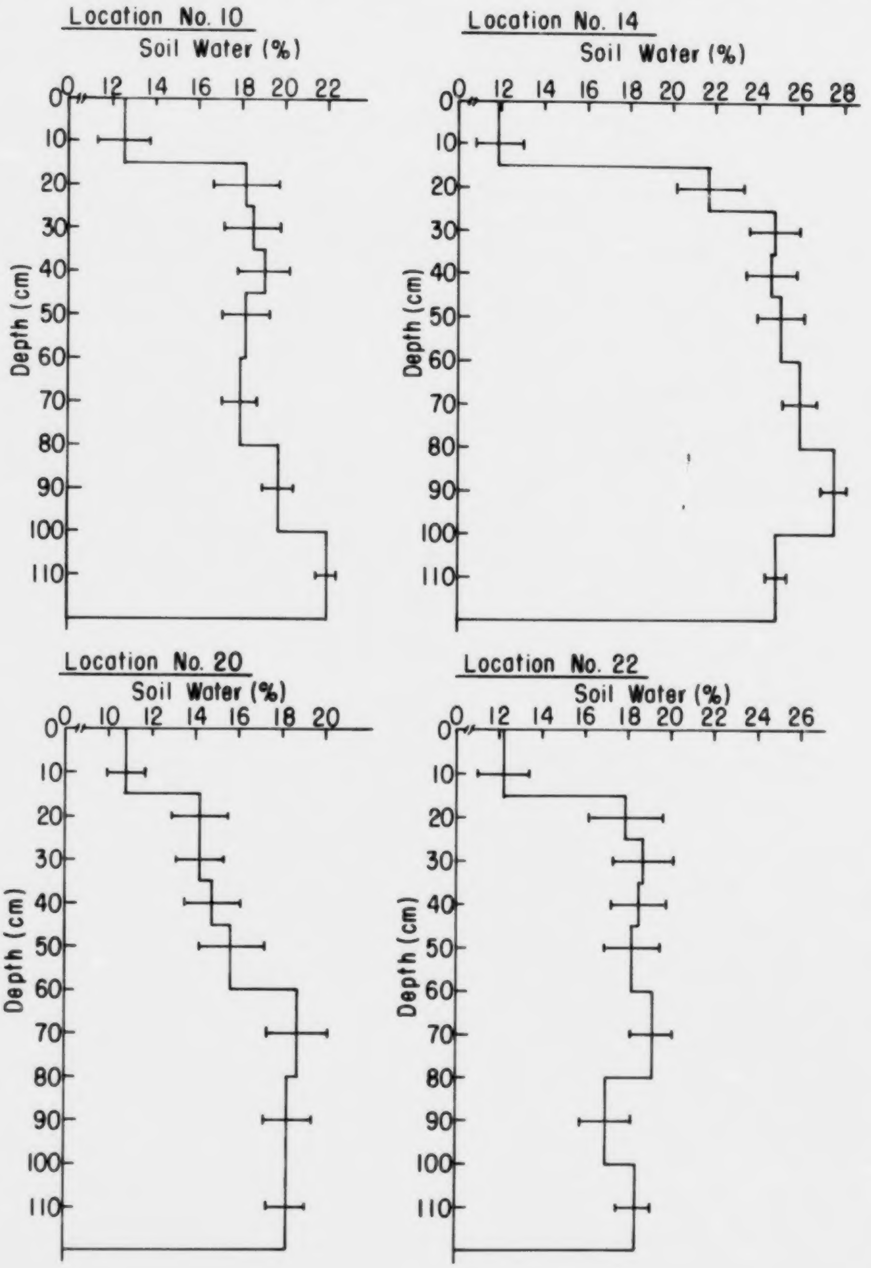


Figure H-5. Soil profiles with depths of 110 cm.

APPENDIX I

TABLE I-1. SAMPLING DATE, PRECIPITATION INSOAK, SOIL WATER CONTENT CHANGE AND SOIL WATER USE RATE PER PERIOD

Day1[1/]	Day2[2/]	Days	Ppt.[3/] Insoak (mm)	Soil Profile Sections (cm)								Total Soil Water (mm)	Soil Water[4/] Use Rate (mm/day)
				0-15	15-25	25-35	35-45	45-60	60-80	80-100	100-120		
6194[5/] N=7[8/]	6220	26	39	-16.9[6/] *[9/]	-14.3 *	-8.7 *	-6.0 *	-3.3 0.06	-1.0 0.70	--[7/]	-	-50.4 *	3.44 *
6220 N=29	6235	15	9	-1.9 *	-4.8 *	-6.1 *	-5.9 *	-7.1 *	-4.5 *	0.0 1.0	-1.0 0.51	-23.2 *	2.15 *
6235 N=29	6262	27	52	2.0 *	3.3 *	1.6 *	-0:6 0.37	-4.7 *	-8.9 *	-6.7 *	-2.5 0.34	-4.8 0.22	2.10 *
6262 N=29	6296	34	71	-3.0 *	-5.3 *	-4.6 *	-3.9 *	-4.4 *	-5.5 *	-7.0 *	-5.5 *	-24.0 *	2.79 *
6296 N=29	6325	29	52	4.8 *	5.1 *	3.1 *	2.1 *	1.3 0.10	-0.1 0.93	1.9 0.62	-2.3 *	16.9 *	1.21 *
6325 N=29	6360	35	50	-3.4 *	0.8 0.32	2.1 *	1.5 *	1.7 *	0.4 0.58	-1.9 0.58	1.7 0.34	1.7 0.55	1.38 *
6360 N=29	7020	25	37	7.7 *	5.7 *	2.0 *	0.8 *	0.8 *	0.0 1.0	0.2 0.62	-0.7 0.39	16.2 *	0.83 *
7020 N=29	7090	70	20	-0.1 0.87	-0.6 0.20	-0.1 0.79	0.5 *	0.9 *	0.7 0.14	0.4 0.31	0.5 0.39	0.9 0.54	0.27 *
7090 N=29	7112	22	24	3.4 *	3.9 *	3.3 *	1.9 *	2.3 *	1.1 0.22	-0.7 0.11	1.3 0.39	14.0 *	0.45 *
7112 N=29	7130	18	8	-3.0 *	-0.9 0.08	0.4 0.12	1.0 *	1.1 *	0.1 0.84	1.1 *	-1.0 0.42	-1.7 0.15	0.54 *
7130 N=7	7148	18	50	13.0 *	9.1 *	6.3 *	5.4 *	1.7 0.13	0.5 0.50	0.5 0.50	- -	32.4 *	0.98 *

(Continued)

TABLE I-1. (Continued)

Day1[1/]	Day2[2/]	Days	Ppt.[3/] Insoak (mm)	Soil Profile Sections (cm) 0-15	15-25	25-35	35-45	45-60	60-80	80-100	100-120	Total Soil Water (mm)	Soil Water [4/] Use Rate (mm/day)
7148 N=7	7154	6	0	-9.6 *	-5.7 *	-2.7 *	0.4 0.59	2.0 0.32	0.5 0.80	0.0 1.0	-	-16.3 *	2.72 *
7154 N=7	7163	9	5	-6.7 *	-5.3 *	-1.8 *	-1.0 0.08	1.3 *	1.0 0.50	0.5 0.50	- -	-13.3 *	2.03 *
7163 N=7	7176	13	46	10.4 *	7.0 *	3.3 *	1.2 0.28	1.7 0.44	3.0 0.59	2.0 0.63	- -	23.3 *	1.75 *
7176 N=7	7185	9	7	-10.3 *	-6.1 *	-2.8 *	-0.8 0.10	1.0 0.23	1.0 -	2.0 0.30	- -	-18.1 *	2.78 *
7185 N=7	7190	5	28	4.3 *	2.6 *	0.3 0.75	-0.6 0.59	-1.0 0.61	-1.0 0.76	-0.3 0.91	-	6.1 0.30	4.38 *
7190 N=5	7206	16	134	14.0 *	9.6 *	9.0 *	6.3 *	10.3 0.14	10.0 0.43	-0.5 0.50	- -	47.4 *	5.41 *
7206 N=6	7214	8	31	-4.8 0.16	-3.2 *	-2.2 *	-1.4 *	-1.5 0.32	-2.0 -	-0.5 0.50	- -	-13.5 *	5.56 *
7214 N=6	7221	7	1	-4.8 0.29	-6.8 *	-5.3 *	-2.5 0.29	3.0 0.37	3.5 0.39	3.0 0.50	- -	-32.8 *	4.83 *
7221 N=6	7226	5	0	-12.8 *	-9.7 *	-6.5 *	-5.0 *	-3.0 0.66	-4.0 0.63	-2.0 0.76	- -	-24.2 *	4.84 *
7226 N=6	7232	6	6	-0.2 0.87	-2.2 *	-2.8 *	-3.2 *	-3.7 0.07	1.0 0.80	3.0 0.50	-	-8.0 0.07	2.33 0.59
7232 N=6	7255	23	74	2.8 *	0.3 0.53	-1.5 0.08	-2.0 0.21	-4.0 0.30	-7.0 0.54	-4.5 0.32		-7.5 0.42	3.54 *
7255 N=6	7263	8	4	-0.3	-0.5	-0.8	-0.8	-2.5	-3.0	-1.0	-	-5.5	1.19

(Continued)

TABLE I-1. (Continued)

Day1[1/]	Day2[2/]	Days	Ppt.[3/] Insoak (mm)	Soil Profile Sections (cm) 0-15	15-25	25-35	35-45	45-60	60-80	80-100	100-120	Total Soil Water (mm)	Soil Water [4/] Use Rate (mm/day)
7263 N=6	7268	5	13	0.0 -	0.0 -	0.0 -	-0.4 0.48	0.3 0.64	0.0 1.0	0.0 1.0		-0.2 0.81	2.63 *
7268 N=6	7288	20	31	3.3 *	2.7 *	0.8 0.09	0.4 0.59	-0.7 0.39	-2.5 0.13	-1.0 0.50		5.0 0.08	1.30
7288 N=6	7298	10	39	-2.3 *	-1.5 *	0.0 1.0	0.0 1.0	-0.7 0.39	-1.0 0.50	-2.0 0.30		-5.3 *	4.43 *
7298 N=6	7303	5	12	0.8 *	0.2 0.74	-0.7 0.10	-0.2 0.62	0.5 0.18	1.5 0.50	1.5 0.20	-	1.7 0.43	2.06
7303 N=6	7317	14	41	3.0 *	1.7 *	1.2 *	0.6 0.21	1.0 0.25	0.5 0.50	0.0 1.0	- -	7.2 *	2.4 *
7317 N=6	7325	8	9	-2.2 *	0.2 0.61	0.2 0.61	-0.4 0.18	-0.7 0.39	-2.0 0.30	-1.5 0.20		-4.3 0.07	1.66
7325 N=6	7333	8	7	-2.2 *	-2.5 *	-1.0 0.08	-0.2 0.62	0.3 0.64	1.0 0.70	2.0 -		-4.2 0.14	1.40 *
7333 N=6	7338	5	0	-0.2 0.36	-0.3 0.17	0.2 0.36	0.2 0.37	0.5 0.18	1.0 -	0.0 1.0	-	0.33 0.70	-0.07 0.70
7338 N=6	7352	14	1	-0.3 0.17	-0.7 *	-0.8 *	-0.6 0.07	-1.5 *	-2.0 0.30	-1.5 0.20	- -	-4.7 *	0.40 *
7352 N=6	8010	23	76	13.0 *	16.8 *	9.7 *	2.6 *	2.0 *	2.0 0.30	2.5 0.34		44.5 *	1.37
8010 N=6	8022	12	0	-6.2 *	-5.2 *	-0.7 0.44	1.8 *	0.5 0.50	0.5 0.50	-0.5 0.50	- -	-10.2 *	0.85 *
8022 N=6	8043	21	5	-1.2 *	-1.8 *	-0.7 0.17	0.2 0.37	2.0 0.39	-1.5 0.20	-1.5 0.20		-3.5 0.23	0.40 *

(Continued)

TABLE I-1. (Continued)

Day1[1]	Day2[2]	Days	Ppt.[3] Insoak (mm)	Soil Profile Sections (cm) 0-15	15-25	25-35	35-45	45-60	60-80	80-100	100-120	Total Soil Water (mm)	Soil Water [4] Use Rate (mm/day)
8043	8060	17	2	-1.7 *	-1.2 *	-0.5 0.42	0.2 0.70	-1.0 0.67	1.5 0.74	4.0 0.63	-	-1.0 0.85	0.18 0.58
8060 N=6	8115	55	20	20.3 *	11.5 *	8.2 *	7.6 *	10.3 0.13	0 1.0	-4.5 0.56	- -	50.7 *	-0.56 *
8115 N=6	8120	5	3	-3.5 0.12	1.33 0.35	1.0 0.30	1.0 0.46	0.3 0.84	-1.5 0.20	-0.5 0.50	-	-1.2 0.81	0.83 0.40
8120 N=6	8143	23	87	-10.5 *	-6.8 *	-3.7 0.09	-1.4 0.53	-0.3 0.93	3.5 0.09	1.5 0.50	- -	-19.8 0.06	4.78 *
8143 N=6	8147	4	11	5.3 *	4.8 *	2.8 *	2.2 0.07	3.0 0.10	-2.0 0.30	-0.5 0.50	- -	15.8 *	-1.21 0.20
8147 N=6	8157	10	0	-5.2 *	-4.5 *	-0.7 .73	3.8 0.17	4.7 0.19	7.5 0.28	8.5 0.37	- -	2.3 0.71	-0.23 0.71
8157 N=6	8220	63	198	14.3 *	3.7 *	2.7 0.15	-3.2 0.26	-2.0 0.61	-2.5 0.50	-5.5 0.36	- -	13.2 *	2.93 *
8220 N=6	8235	15	54	-5.8 *	-4.3 *	-5.0 *	-4.8 *	-6.3 0.06	-1.5 0.20	0.5 0.50		-23.7 *	5.18 *
8235 N=6	8268	33	37	-13.3 *	-10.3 *	-11.5 *	-10.2 *	-13.5 *	-5.0 *	-2.5 0.34	- -	-55.3 *	2.80 *
8268 N=29	8337	69	90	-3.0 *	-2.9 *	-0.3 0.31	0.3 0.20	0.3 0.38	-2.1 *	-5.4 *	-5.5 0.09	-8.97 *	1.43 *
8337 N=6	8352	15	52	8.3 *	7.0 *	6.5 *	4.0 0.08	2.75 0.14	2.0 0.30	1.5 0.20	- -	28.3 *	1.58 *
8352 N=6	9021	34	89	17.2 *	9.8 *	8.5 *	7.2 *	8.0 0.14	-0.5 0.79	0.0 -	- -	46.5 *	1.25 *

(Continued)

TABLE I-1. (Continued)

Day1[1]	Day2[2]	Days	Ppt.[3] Insoak (mm)	Soil Profile Sections (cm) 0-15	15-25	25-35	35-45	45-60	60-80	80-100	100-120	Total Soil Water (mm)	Soil Water[4] Use Rate (mm/day)
9021	9049	28	8	-15.2	-2.5	-2.7	-1.4	-0.7	2.7	-2.4	-1.0	-22.9	0.24
N=29				*	*	*	*	0.23	0.17	*	0.09	*	*

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[1] Day 1 - Preceeding sampling date.
[2] Day 2 - Next succeeding sampling date.
[3] Precipitation Insoak - (Precipitation-Runoff).
[4] Soil Water Use Rate = (Ppt. Insoak-[Total Soil Water on Day 1 - Total Soil Water on Day 2])/Days.
[5] When N 29, difference in Total Soil Water Calculated by regression equations.
[6] Plant Year Date (e.g., 6____ = 1976; _194=194 days after 1 November (1 Nov: = 1, 31 Oct. = 365).
[7] Difference in soil water (Day 1-Day 2) for that soil profile section.
[8] No soil water reading at this depth on one or both dates.
[9] Number of location sampled.
Probability level; * = P 0.05.

APPENDIX J

AVERAGE (N=25) PLANT BIOMASS ($\bar{X}$±SE; KG/HA, OVEN-DRY) COMPONENTS ON A TALLGRASS PRAIRIE WATERSHED GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-78

	Live		Standing Dead		Standing Live + Dead		Ground Litter	
Date[1]	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
6163	310	40	1570	290	1870	310	1440	220
6183	630	30	1250	230	1880	240	2200	320
6206	1300	140	1330	190	2630	240	2480	400
6234	1420	110	1280	190	2700	270	2980	720
6262	950	85	1320	170	2280	230	2920	410
6290	1160	105	1260	160	2420	240	2860	440
6320	960	115	1400	210	2370	270	3540	950
6346	-[2]	-	2340	270	2340	270	1970	330
7010	-	-	2310	290	2310	290	2710	450
7040	-	-	1530	250	1530	250	2560	400
7090	-	-	1890	250	1890	250	2210	210
7130	-	-	1320	290	1320	290	2020	410
7160	-	-	1420	250	1420	250	1430	170
7180	460	25	1100	190	1560	190	1760	250
7192	910	40	840	160	1750	180	2100	520
7220	1440	90	730	120	2170	180	1380	280
7250	1250	85	650	70	1890	130	1040	160
7275	1060	125	960	140	2030	240	1430	170
7312	1310	170	860	100	2170	240	2210	520
7347	-	-	1750	160	1750	160	1920	410
8017	-	-	1520	200	1520	200	4420	1960
8050	-	-	1410	180	1410	180	2100	360
8120	-	-	1630	270	1630	270	2740	440
8148	15	1	1000	130	1020	130	1540	210
8176	420	35	880	170	1300	180	1090	230
8205	900	65	950	170	1860	190	2400	490
8233	1500	110	1030	100	2530	140	1920	370
8254	1630	160	1070	100	2700	220	1480	310
8290	1630	125	1150	100	2780	200	1480	290
8317	1020	115	1170	160	2190	240	1900	410
8343	850	115	1420	150	2270	230	2460	390

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[1] Plant year date; 6---=1976, 6163 = 163 days after 1 November 1975.

[2] Live vegetation not separated from standing dead.

APPENDIX K

LIST OF PLANT SPECIES FOUND ON TALLGRASS PRAIRIE WATERSHED GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-78

Family	Genus	Species	Common	Code
-----GRASSES-----				
Gramineae	Aegilops	cylindrica	Goatgrass	AECY
Gramineae	Agropyron	smithii	Western Wheatgrass	AGSM
Gramineae	Agrostis	spp.	Agrostis	AGR
Gramineae	Andropogon	gerardi	Big Bluestem	ANGE
Gramineae	Andropogon	ternarius	Slitbeard Bluestem	ANTE2
Gramineae	Andropogon	virginicus	Broomsedge Bluestem	ANVI2
Gramineae	Brothriochloa	saccharoides	Silver Bluestem	BOSA
Gramineae	Brothriochloa	spp.	Oldworld Bluestem	BOTHR
Gramineae	Bouteloua	curtipendula	Sideoats Grama	BOCU
Gramineae	Bouteloua	gracilis	Blue Grama	BOGR2
Gramineae	Bouteloua	hirsuta	Hairy Grama	BOHI2
Gramineae	Bromus	japonicus	Japanese Brome	BRJA
Gramineae	Bromus	techtorum	Cheatgrass	BRTE
Gramineae	Bromus	uniolodes		BRUN
Gramineae	Buchloe	dactyloides	Buffalograss	BUDA
Gramineae	Chloris	verticillata	Tumble Windmillgrass	CHVE2
Gramineae	Cynodon	dactylon	Bermudagrass	CYDA
Gramineae	Digitaria	spp.	Crabgrass	DIGI2
Gramineae	Elymus	canadensis	Canada Wildrye	ELCA4
Gramineae	Elymus	virginicus	Virginia wildrye	ELVI3
Gramineae	Eragrostis	cilianensis	Stinkgrass	ERCI
Gramineae	Eragrostis	spectabilis	Purple Lovegrass	ERSP
Gramineae	Eragrostis	spp.	Lovegrass	ERAGR
Gramineae	Eriochloa	gracilis	Southwestern Cupgrass	ERGR4
Gramineae	Hordeum	pusillum	Little Barley	HOPU

(Continued)

APPENDIX K (Continued)

Family	Genus	Species	Common	Code
Gramineae	Leptoloma	cognatum	Fall Witchgrass	LECO
Gramineae	Manisuris	cylindrica	Carolina Jointtail	MACY
Gramineae	Muhlenbergia	spp.	Muhly	MUHLE
Gramineae	Panicum	scribnerianum	Scribners Panicum	PASC5
Gramineae	Panicum	spp.	Panicum	PANIC
Gramineae	Panicum	virgatum	Switchgrass	PAVI2
Gramineae	Paspalum	spp.	Paspalum	PASP2
Gramineae	Poa	spp.	Bluegrass	POA
Gramineae	Schedonnardus	paniculatus	Tumblegrass	SCPA
Gramineae	Schizachyrium	scoparium	Little Bluestem	SCSC
Gramineae	Setaria	spp.	Bristlegrass	SETAR
Gramineae	Sorghastrum	nutans	Indiangrass	SONU2
Gramineae	Sporobolus	spp.	Dropseed	SPORO
Gramineae	Tridens	flavus	Purpletop	TRFL2
Gramineae	Tridens	spp.	Tridens	TRIDE
Gramineae	Vulpia	octofolia	Six-Weeks Fescue	VUOC
------------------------FORBS------------------------				
Acanthaceae	Ruellia	ciliosa	Fringeleaf Ruellia	RUAC
Apocynaceae	Apocynum	spp.	Dogbane	APOCY
Asclepiadaceae	Asclepias	spp.	Milkweed	ASCLE
Boraginaceae	Lithospermum	spp.	Gromwell	LITHO
Campanulaceae	Triodanis	spp.	Venus' Looking Glass	TRIOD
Caryophyllaceae	Spergularia	echinosperma	Sandspurry	SPEC
Caryophyllaceae	Stellaria	media	Starwort Chickweed	STME2
Commelinaceae	Aneilema	spp.		ANEIL
Commelinaceae	Tradescantia	ohiensis	Spiderwort	TROH
Compsitae	Achillea	lanulosa	Western Yarrow	ACLA
Compositae	Ambrosia	psilostachya	Western Ragweed	AMPS

(Continued)

APPENDIX K (Continued)

Family	Genus	Species	Common	Code
Compositae	Antennaria	neglecta	Pussytoes	ANNE
Compositae	Artemisia	ludoviciana	Louisiana Sagewort	ARLU
Compositae	Chrysopsis	pilosa	Soft Goldaster	CHPI2
Compositae	Cirsium	spp.	Thistle	CIRSI
Compositae	Echinaceae	angustifolia	Blacksamson	ECAN2
Compositae	Erigeron	canadensis	Horseweed Fleabane	ERCA5
Compositae	Erigeron	ramosus	Daisy Fleabane	ERRA
Compositae	Erigeron	strigosus	Rough Fleabane	ERST3
Compositae	Eupatorium	rugosum	White Snakeroot	EURU
Compositae	Eupatorium	spp.	Eupatorium	EUPAT
Compositae	Gaillardia	fastigiata	Prairie Gaillardia	GALAF
Compositae	Gaillardia	spp.	Gaillardia	GAILL
Compositae	Gnaphalium	spp.	Cudweed	GNAPH
Compositae	Grindelia	squarrosa	Curlycup Gumweed	GRSQ
Compositae	Hieracium	longipilum	Longbeard Hawkweed	HILO2
Compositae	Hymenopappus	spp.	Wooly White	HYME4
Compositae	Kuhnia	eupatoroides	False Boneset	KUEU
Compositae	Lactuca	canadensis	Canada Lettuce	LACA
Compositae	Liatris	punctata	Dotted Gayfeather	LIPU
Compositae	Ratibida	columnaris	Upright Prairiecone	RATIB
Compositae	Rudbeckia	nitida	Shiny Coneflower	RUNI3
Compositae	Rudbeckia	hirta	Blackeyedsusan	RUHI2
Compositae	Solidago	spp.	Goldenrod	SOLID
Compositae	Taraxacum	officinale	Dandelion	TAOF
Compositae	Vernonia	baldwini	Western Ironweed	VEBA
Compositae	Xanthocephalum	dracunculoides	Common Broomweed	XADR
Cruciferae	Barbarea	verna	Early Wintercress	BAVE
Cruciferae	Capsella	bursa-pastoris	Common Shepherds Purse	CABU2
Cruciferae	Lepidium	densiflorum	Prairie Pepperweed	LEDE
Cruciferae	Lepidium	spp.	Pepperweed	LEPID

(Continued)

APPENDIX K (Continued)

Family	Genus	Species	Common	Code
Euphorbiaceae	Croton	texensis	Texas Croton	CRTE4
Euphorbiaceae	Euphorbia	marginata	Snow on the Mountain	EUMA8
Euphorbiaceae	Tragia	urticifolia	Nettle-Leaf Noseburn	TRUR2
Gentianacee	Sabatia	campestris	Prairie Rosegentian	SACA
Geraniaceae	Geranium	spp.	Geranium	GERAN
Iridaceae	Sisyrinchium	spp.	Blueeye-Grass	SISYR
Labiatae	Hedeoma	spp.	Pennyroyal	HEDEO
Labiatae	Labiatae	spp.	Mint	LAB
Labiatae	Lamium	spp.	Henbit	LAMIU
Labiatae	Marrubium	spp.	Horehound	MARRU
Labiatae	Monarda	pectinata	Plains Beebalm	MOPE
Labiatae	Monarda	spp.	Beebalm	MONAR
Labiatae	Salvia	pitcheri	Pitchers Sage	SAPI3
Leguminosae	Acacia	angustissima	Prairie Acacia	ACAN
Leguminosae	Amorpha	canescens	Leadplant	AMCA6
Leguminosae	Cassia	fasciculata	Showy Partridgepea	CAFA
Leguminosae	Desmodium	sessilifolium	Sessile Tickclover	DESE
Leguminosae	Krameria	spp.	Ratany	KRAME
Leguminosae	Lespedeza	spp.	Lespedeza	LESPE
Leguminosae	Lespedeza	virginica	Slender Lespedeza	LEVI7
Leguminosae	Neptunia	lutea	Yellow Neptunia	NELU2
Leguminosae	Oxytropis	spp.	Crazyweed	OXYTR
Leguminosae	Petalostemon	candidum	White Prairieclover	PECAN
Leguminosae	Psoralea	tenuiflora	Wild Alfalfa	PSTE3
Leguminosae	Schrankia	uncinata	Catclaw Sensitivebriar	SCUN
Leguminosae	Astragalus	caryocarpus	Groundplum Milkvetch	ASCA
Leguminosae	Baptisia	spp.	Wildindigo	BAPTI
Liliaceae	Allium	spp.	Onion	ALLIU
Linaceae	Linum	rigidum	Stiffstem Flax	LIRI
Linaceae	Linum	spp.	Flax	LINUM

(Continued)

APPENDIX K (Continued)

Family	Genus	Species	Common	Code
Malvaceae	Callirhoe	involucrata	Low Poppymallow	CAIN2
Malvaceae	Malvaceae	spp.	Mallow	MAL
Onagraceae	Oenothera	serrulata	Halfshrub Sundrop	OESE
Oxalidaceae	Oxalis	corniculata	Yellow Woodsorrel	OXCO
Plantaginaceae	Plantago	purshii	Woolly Plantain	PLPA2
Polygonaceae	Eriogonum	annuum	Annual Wildbuckwheat	ERAN
Polygonaceae	Polygonum	spp.	Smartweed	POLYG
Polygonaceae	Rumex	ellipticus	Dock	RUEL
Ranunculaceae	Ranunculus	spp.	Buttercup spp.	Ranun
Rubiaceae	Diodia	teres	Rough Buttonweed	DITE2
Rubiaceae	Diodia	virginiana	Virginia Buttonweed	DIVI3
Rubiaceae	Galium	spp.	Bedstraw	GALIU
Rubiaceae	Houstonia	nigricans	Narrowleaf Bluet	HONI
Solanaceae	Physalis	mollis	Field Groundcherry	PHVIM
Solanaceae	Solanum	rostratum	Buffalobur	SORO
Umbelliferae	Daucus	carota	Wild Carrot	DACA6
Urticaceae	Urtica	spp.	Nettle	URTIC
Verbenaceae	Verbena	spp.	Verbena	VERBE
----------WOODY PLANTS----------				
Anacardiaceae	Rhus	glabra	Smooth Sumac	RHGL
Anacardiaceae	Rhus	spp.	Sumac	RHUS
Cactaceae	Ferocactus	acanthodes	Cactus	FEAC
Cactaceae	Opuntia	spp.	Prickly Pear	OPUNT
Caprifoliaceae	Symphoricarpos	orbiculatus	Buckbrush	SYOR
Compositae	Chrysothamnus	viscidiflorus	Rabbitbrush	CHVI
Cornaceae	Cornus	drummondii	Roughleaf Dogwood	CODR
Cornaceae	Cornus	spp.	Dogwood	CORNU
Fagaceae	Quercus	spp.	Oak	QUERC

(Continued)

APPENDIX K (Continued)

Family	Genus	Species	Common	Code
Liliaceae	Yucca	glauca	Small Soapweed	YUGL
Pinaceae	Juniperus	virginiana	Eastern Redcedar	JUVI
Rosaceae	Crataegus	viridus	Hawthorne	CRVI
Rosaceae	Prunus	angustifolia	Chickasaw Plum	PRAN3
Rosaceae	Rubus	spp.	Blackberry spp.	RUBUS
Rosaceae	Rubus	trivialis	Southern Dewberry	RUTR
Simaroubaceae	Ailanthus	altissima	Tree-of-Heaven	HIAL
Ulmaceae	Ulmus	americana	American Elm	ULAM
Ulmaceae	Ulmus	spp.	Elm	ULMUS

APPENDIX L

AVERAGE (N=25) CHEMICAL COMPOSITION (%, $\bar{X}\pm SE$) IN ABOVEGROUND VEGETATION COMPONENTS ON A TALLGRASS PRAIRIE WATERSHED GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-78

TABLE L-1. AVERAGE (25 SAMPLES/DAY) NITROGEN (%) IN ABOVEGROUND VEGETATION COMPONENTS ON A TALLGRASS PRAIRIE GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-78

	Live		Standing Dead		Ground Litter		Dung	
Day[1]	$\bar{X}$	SE[2]	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
6163	2.24	0.05	0.84	0.07	1.01	0.05	1.63	0.03
6183	1.91	0.07	0.94	0.08	1.21	0.06	1.56	0.05
6206	1.81	0.08	1.02	0.04	1.13	0.07	1.86	0.06
6234	1.49	0.06	0.93	0.04	1.13	0.07	2.02	0.05
6262	1.37	0.07	0.81	0.04	1.09	0.05	1.78	0.05
6290	1.30	0.10	0.85	0.03	1.14	0.08	2.14	0.05
6320	1.42	0.09	0.93	0.06	1.12	0.06	1.72	0.03
6346	--[3]	--	1.10	0.06	1.24	0.07	1.94	0.06
7010	--	--	0.93	0.08	0.96	0.06	1.74	0.04
7040	--	--	0.90	0.05	1.12	0.09	1.78	0.05
7090	--	--	0.94	0.05	0.99	0.09	1.83	0.06
7130	--	--	0.71	0.08	0.98	0.06	1.65	0.05
7160	--	--	1.17	0.13	--	--	--	--
7192	2.27	0.16	1.06	0.07	--	--	--	--
7220	1.24	0.05	0.77	0.05	--	--	--	--
7250	1.13	0.04	0.98	0.10	--	--	--	--
7275	--	--	--	--	--	--	--	--
7312	1.23	0.07	0.87	0.05	--	--	--	--
7347	--	--	0.96	0.07	--	--	--	--
8017	--	--	0.71	0.04	--	--	--	--
8050	--	--	0.67	0.04	--	--	--	--
8120	--	--	0.65	0.03	--	--	--	--
8148	--	--	0.77	0.06	--	--	--	--
8176	2.16	0.06	0.78	0.04	--	--	--	--
8205	1.46	0.04	0.83	0.04	--	--	--	--
8233	1.19	0.05	0.75	0.03	--	--	--	--
8254	1.04	0.03	0.66	0.03	--	--	--	--
8290	1.10	0.05	0.66	0.02	--	--	--	--
8317	0.93	0.05	--	--	--	--	--	--
8343	0.92	0.05	0.72	0.03	--	--	--	--

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[1] Plant year date: 6_ _ _ = 1976; 6163 = 163 days after 1 Nov. 75.
[2] Standard error.
[3] Chemical analysis not conducted.

TABLE L-2. AVERAGE (25 SAMPLES/DAY) PHOSPHORUS (%) IN ABOVEGROUND VEGETATION COMPONENTS ON A TALLGRASS PRAIRIE GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-78

	Live		Standing Dead		Ground Litter		Dung	
Day[1]	$\bar{X}$	SE[2]	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
6163	0.18	0.00	0.04	0.003	0.06	0.01	0.21	0.01
6183	0.16	0.01	0.06	0.006	0.09	0.01	0.22	0.02
6206	0.11	0.01	0.05	0.003	0.08	0.01	0.24	0.02
6234	0.07	0.01	0.04	0.003	0.09	0.01	0.21	0.01
6262	0.08	0.01	0.03	0.002	0.06	0.01	0.19	0.02
6290	0.09	0.01	0.04	0.003	0.07	0.01	0.21	0.01
6320	0.09	0.01	0.05	0.005	0.06	0.01	0.21	0.01
6346	--[3]	--	0.06	0.006	0.07	0.01	0.26	0.03
7010	--	--	0.04	0.004	0.06	0.01	0.13	0.02
7040	--	--	0.04	0.004	0.07	0.01	0.26	0.02
7090	--	--	0.04	0.003	0.09	0.01	0.27	0.02
7130	--	--	0.04	0.007	0.06	0.01	0.21	0.01
7160	--	--	0.10	0.023	--	--	--	--
7192	0.11	0.01	0.05	0.005	--	--	--	--
7220	0.10	0.01	0.04	0.006	--	--	--	--
7250	0.07	0.00	0.05	0.005	--	--	--	--
7275	--	--	--	--	--	--	--	--
7312	0.09	0.01	0.04	0.004	--	--	--	--
7347	--	--	0.07	0.009	--	--	--	--
8017	--	--	0.08	0.007	--	--	--	--
8050	--	--	0.04	0.003	--	--	--	--
8120	--	--	0.03	0.003	--	--	--	--
8148	--	--	0.05	0.007	--	--	--	--
8176	0.20	0.01	0.05	0.005	--	--	--	--
8205	0.11	0.01	0.06	0.005	--	--	--	--
8233	0.09	0.00	0.05	0.004	--	--	--	--
8254	0.08	0.01	0.04	0.004	--	--	--	--
8290	0.09	0.01	0.04	0.003	--	--	--	--
8317	0.08	0.01	--	--	--	--	--	--
8343	0.15	0.04	0.05	0.000	--	--	--	--

[1] Plant year date: 6_ _ _ = 1976; 6163 = 163 days after 1 Nov 75.

[2] Standard error.

[3] Chemical analysis not conducted.

TABLE L-3. AVERAGE (25 SAMPLES/DAY) POTASSIUM (%) IN ABOVEGROUND VEGETATION COMPONENTS ON A TALLGRASS PRAIRIE GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-78

	Live		Standing Dead		Ground Litter		Dung	
Day[1]	$\bar{X}$	SE[2]	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
6163	1.90	0.08	0.12	0.01	0.16	0.01	0.17	0.01
6183	1.60	0.08	0.18	0.02	0.25	0.01	0.18	0.01
6206	1.37	0.04	0.21	0.02	0.22	0.01	0.23	0.04
6234	1.28	0.06	0.32	0.03	0.22	0.01	0.23	0.02
6262	1.17	0.09	0.27	0.02	0.20	0.01	0.22	0.03
6290	1.22	0.06	0.25	0.02	0.20	0.01	0.20	0.01
6320	1.17	0.07	0.37	0.04	0.21	0.01	0.20	0.02
6346	--[3]	--	0.51	0.05	0.23	0.02	0.20	0.04
7010	--	--	0.37	0.03	0.21	0.02	0.25	0.02
7040	--	--	0.24	0.03	0.21	0.02	0.31	0.02
7090	--	--	0.16	0.03	0.20	0.01	0.32	0.03
7130	--	--	0.17	0.06	0.19	0.03	0.21	0.03
7160	--	--	0.61	0.13	--	--	--	--
7192	1.68	0.08	0.38	0.06	--	--	--	--
7220	1.37	0.10	0.38	0.04	--	--	--	--
7250	1.13	0.08	0.54	0.05	--	--	--	--
7275	--	--	--	--	--	--	--	--
7312	1.35	0.09	0.53	0.02	--	--	--	--
7347	--	--	0.72	0.06	--	--	--	--
8017	--	--	0.37	0.05	--	--	--	--
8050	--	--	0.21	0.02	--	--	--	--
8120	--	--	0.10	0.02	--	--	--	--
8148	--	--	0.23	0.05	--	--	--	--
8176	2.41	0.08	1.03	0.20	--	--	--	--
8205	1.74	0.04	0.38	0.06	--	--	--	--
8233	1.63	0.10	0.30	0.03	--	--	--	--
8254	1.55	0.08	0.51	0.03	--	--	--	--
8290	1.42	0.07	0.25	0.02	--	--	--	--
8317	1.14	0.05	--	--	--	--	--	--
8343	0.99	0.04	0.22	0.02	--	--	--	--

[1] Plant year date: 6_ _ _ = 1976; 6163 = 163 days after 1 Nov 75.

[2] Standard Error.

[3] Chemical analysis not conducted.

TABLE L-4. AVERAGE (25 SAMPLES/DAY) CALCIUM (%) IN ABOVEGROUND VEGETATION COMPONENTS ON A TALLGRASS PRAIRIE GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-78

	Live		Standing Dead		Ground Litter		Dung	
Day[1]	$\bar{X}$	SE[2]	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
6130	0.50	0.02	0.44	0.03	0.58	0.03	0.82	0.04
6183	0.58	0.04	0.56	0.05	0.67	0.03	0.85	0.05
6206	0.56	0.03	0.51	0.03	0.65	0.04	0.96	0.04
6234	0.54	0.05	0.48	0.02	0.64	0.04	0.87	0.04
6262	0.48	0.03	0.51	0.02	0.55	0.03	0.84	0.05
6290	0.62	0.07	0.49	0.02	0.65	0.04	0.89	0.03
6320	0.58	0.05	0.52	0.03	0.66	0.05	0.96	0.03
6346	--[3]	--	0.38	0.01	0.62	0.04	1.05	0.07
7010	--	--	0.45	0.03	0.50	0.06	0.68	0.04
7040	--	--	0.50	0.03	0.54	0.05	0.86	0.03
7090	--	--	0.45	0.03	0.36	0.03	0.88	0.05
7130	--	--	0.39	0.03	0.54	0.05	0.90	0.02
7160	--	--	0.49	0.02	--	--	--	--
7192	0.59	0.03	0.50	0.04	--	--	--	--
7220	0.55	0.04	0.44	0.03	--	--	--	--
7250	0.55	0.03	0.57	0.05	--	--	--	--
7275	--	--	--	--	--	--	--	--
7312	0.66	0.04	0.25	0.02	--	--	--	--
7347	--	--	0.48	0.03	--	--	--	--
8017	--	--	0.42	0.04	--	--	--	--
8050	--	--	0.49	0.04	--	--	--	--
8120	--	--	0.34	0.02	--	--	--	--
8148	--	--	0.43	0.02	--	--	--	--
8176	0.62	0.03	0.42	0.02	--	--	--	--
8205	0.57	0.04	0.42	0.02	--	--	--	--
8233	0.64	0.06	0.41	0.02	--	--	--	--
8254	0.64	0.04	0.46	0.03	--	--	--	--
8290	0.61	0.05	0.45	0.02	--	--	--	--
8317	0.59	0.06	--	--	--	--	--	--
8343	0.54	0.06	0.47	0.02	--	--	--	--

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[1] Plant year date: 6_ _ _ = 1976; 6163 = 163 days after 1 Nov 75.

[2] Standard error.

[3] Chemical analysis not conducted.

TABLE L-5. AVERAGE (25 SAMPLES/DAY) ASH (%) IN ABOVEGROUND VEGETATION COMPONENTS ON A TALLGRASS PRAIRIE GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-78

	Live			Standing Dead	
Day[1]	$\bar{X}$	SE[2]		$\bar{X}$	SE
6163	--[3]	--		--	--
6183	--	--		--	--
6206	--	--		--	--
6234	--	--		--	--
6262	--	--		--	--
6290	--	--		--	--
6320	--	--		--	--
6346	--	--		--	--
7010	--	--		--	--
7040	--	--		--	--
7090	--	--		--	--
7130	--	--		8.8	0.5
7160	--	--		9.3	9.3
7192	7.5	0.2		8.3	0.3
7220	7.8	0.2		8.0	0.3
7250	6.9	0.2		7.6	0.2
7275	6.6	0.2		7.7	0.3
7312	7.2	0.2		8.0	0.3
7347	--	--		7.0	0.2
8017	--	--		7.4	0.5
8050	--	--		7.7	0.6
8120	--	--		7.7	0.3
8148	--	--	12.0	2.0	
8176	8.5	0.3		7.5	0.3
8205	7.8	0.1		9.3	0.7
8233	8.0	0.2		8.6	0.4
8254	7.9	0.2		7.5	0.3
8290	7.9	0.2		8.8	0.4
8317	7.7	0.3		--	--
8343	--	--		--	--

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[1] Plant year date: 6_ _ _ = 1976, 6163 = 163 days after 1 Nov 75.
[2] Standard error.
[3] Chemical analysis not conducted.

TABLE L-6. AVERAGE (25 SAMPLES/DAY) ACID DETERGENT FIBER (%) IN ABOVEGROUND VEGETATION COMPONENTS ON A TALLGRASS PRAIRIE GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-78

Day[1]	Live $\bar{X}$	Live SE[2]	Standing Dead $\bar{X}$	Standing Dead SE
6163	45.9	0.6	52.8	0.4
6183	46.6	2.2	53.0	0.4
6206	36.7	0.5	51.1	0.6
6234	37.8	0.6	52.0	0.4
6262	40.5	1.3	52.5	0.3
6290	39.3	0.6	50.9	0.5
6320	36.1	0.8	49.5	0.6
6346	--[3]	--	45.3	0.5
7010	--	--	--	--
7040	--	--	--	--
7090	--	--	--	--
7130	--	--	--	--
7160	--	--	--	--
7192	37.6	0.5	47.0	1.2
7220	43.1	0.3	53.1	0.8
7250	43.7	0.9	54.2	1.5
7275	42.2	1.0	53.0	0.4
7312	42.2	0.8	53.2	0.5
7347	--	--	49.8	1.8
8017	--	--	45.1	0.8
8050	--	--	49.8	1.0
8120	--	--	53.3	0.5
8148	--	--	51.9	0.5
8176	30.7	1.1	52.1	0.7
8205	37.6	0.7	48.7	0.9
8233	40.6	0.6	51.9	0.6
8254	39.0	0.6	50.3	0.7
8290	39.0	0.7	50.9	0.5
8317	36.9	0.9	51.3	0.4
8343	--	--	--	--

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[1] Plant year date: 6_ _ _ = 1976; 6163 = 163 days after 1 Nov 75.
[2] Standard error.
[3] Chemical analysis not conducted.

TABLE L-7. AVERAGE (25 SAMPLES/DAY) ACID DETERGENT LIGNIN (%) IN ABOVEGROUND VEGETATION COMPONENTS ON A TALLGRASS PRAIRIE GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-78

	Live		Standing Dead	
Day[1]	$\bar{X}$	SE[2]	$\bar{X}$	SE
6163	11.4	0.4	13.1	0.2
6183	14.9	1.3	12.7	0.8
6206	14.9	1.2	17.5	1.7
6234	11.8	0.5	12.3	0.5
6262	10.1	1.0	12.3	0.3
6290	10.2	0.4	13.3	0.7
6320	10.1	0.6	14.0	0.6
6346	--[3]	--	11.3	0.7
7010	--	--	--	--
7040	--	--	--	--
7090	--	--	--	--
7130	--	--	--	--
7160	--	--	9.0	0.2
7192	6.9	0.2	10.1	0.5
7220	9.2	0.2	10.7	0.4
7250	11.3	0.4	13.5	0.3
7275	10.1	0.3	13.9	0.4
7312	9.3	0.3	14.8	1.1
7347	--	--	12.7	0.6
8017	--	--	13.8	0.6
8050	--	--	10.8	0.8
8120	--	--	14.0	1.3
8148	--	--	11.6	0.6
8176	8.0	0.4	13.0	0.6
8205	9.2	0.6	12.6	0.6
8233	10.4	0.4	15.0	1.8
8254	1.0	0.4	12.9	0.6
8290	8.5	0.7	11.4	0.4
8317	9.0	0.5	--	--
8343	--	--	--	--

[1] Plant year date: 6_ _ _ = 1976; 6163 = 163 days after 1 Nov 75.
[2] Standard error.
[3] Chemical analysis not conducted.

TABLE L-8. AVERAGE (25 SAMPLES/DAY) CELLULOSE (%) IN ABOVEGROUND VEGETATION COMPONENTS ON A TALLGRASS PRAIRIE GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-78

	Live		Standing Dead	
Day[1]	$\bar{X}$	SE[2]	$\bar{X}$	SE
6163	32.3	0.8	39.3	0.5
6183	22.8	0.9	34.4	1.5
6206	29.7	0.4	37.0	1.8
6234	31.4	0.6	37.5	0.3
6262	31.5	0.6	37.8	0.6
6290	30.1	0.7	38.1	0.6
6320	27.8	0.8	37.2	0.6
6346	--[3]	--	33.7	0.8
7010	--	--	--	--
7040	--	--	--	--
7090	--	--	--	--
7130	--	--	--	--
7160	--	--	34.1	0.9
7192	29.8	0.4	37.3	0.4
7220	31.4	0.3	37.9	0.8
7250	31.6	0.8	35.9	0.4
7275	30.6	0.8	35.5	0.7
7312	31.6	0.8	32.5	1.1
7347	--	--	33.9	0.7
8017	--	--	35.0	0.8
8050	--	--	39.7	1.1
8120	--	--	36.1	0.9
8148	--	--	35.6	1.6
8176	23.9	0.7	38.7	0.8
8205	31.2	0.8	38.0	0.6
8233	32.4	0.6	35.4	0.8
8254	31.7	0.4	36.3	0.4
8290	30.7	0.6	35.8	0.4
8317	28.0	0.6	--	--
8343	--	--	--	--

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[1] Plant year date: 6_ _ _ = 1976; 6163 = 163 days after 1 Nov. 75.
[2] Standard error.
[3] Chemical analysis not conducted.

TABLE L-9. AVERAGE (25 SAMPLES/DAY) DRY MATTER DIGESTIBILITY (%) IN ABOVEGROUND VEGETATION COMPONENTS ON A TALLGRASS PRAIRIE GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-78

Day[1]	Live		Standing Dead	
	X̄	SE[2]	X̄	SE
6163	--[3]	--	--	--
6183	--	--	--	--
6206	--	--	--	--
6234	35.4	1.5	6.6	1.2
6262	43.9	1.0	8.7	0.8
6290	50.5	1.2	22.1	1.1
6320	45.0	2.2	18.1	0.9
6346	--	--	30.7	1.7
7010	--	--	--	--
7040	--	--	--	--
7090	--	--	--	--
7130	--	--	--	--
7160	--	--	29.6	2.7
7192	48.2	2.1	16.9	1.8
7220	46.8	1.0	20.3	1.0
7250	49.1	0.9	22.3	1.7
7275	47.2	1.1	23.5	1.0
7312	38.8	0.8	24.6	0.6
7347	--	--	42.5	0.8
8017	--	--	22.0	1.2
8050	--	--	15.8	1.0
8120	--	--	17.8	0.9
8148	--	--	15.0	0.7
8176	58.8	1.2	21.6	0.8
8205	49.4	1.2	18.7	1.3
8233	43.6	0.7	20.4	1.3
8254	45.7	1.2	26.2	1.2
8290	49.7	1.5	21.3	2.4
8317	48.0	2.0	--	--
8343	21.7	2.5	--	--

[1] Plant year date: 6_ _ _ = 1976; 6163 = 163 days after 1 Nov 1975.
[2] Standard error.
[3] Chemical analysis not conducted.

TABLE L-10. AVERAGE (25 SAMPLES/DAY) ORGANIC MATTER DIGESTIBILITY (%) IN ABOVEGROUND VEGETATION COMPONENTS ON A TALLGRASS PRAIRIE GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-78

Day[1]	Live		Standing Dead	
	$\bar{X}$	SE[2]	$\bar{X}$	SE
6163	-- [3]	--	--	--
6183	--	--	--	--
6206	--	--	--	--
6234	--	--	--	--
6262	--	--	--	--
6290	--	--	--	--
6320	--	--	--	--
6346	--	--	--	--
7010	--	--	--	--
7040	--	--	--	--
7090	--	--	--	--
7130	--	--	--	--
7160	--	--	28.7	1.5
7192	49.3	2.5	21.9	1.3
7220	49.3	0.8	23.5	1.4
7250	50.1	0.9	26.2	1.6
7275	49.4	1.4	26.4	1.0
7312	41.3	0.9	26.4	0.8
7347	--	--	44.0	0.8
8017	--	--	23.6	0.7
8050	--	--	18.0	0.8
8120	--	--	19.6	1.0
8148	--	--	15.6	0.4
8176	58.9	2.6	23.4	1.0
8205	50.1	1.2	19.5	1.0
8233	45.2	0.7	22.2	1.3
8254	47.4	1.1	26.9	1.3
8290	51.3	1.4	48.2	0.9
8317	48.7	1.9	--	--
8343	--	--	--	--

[1] Plant year date: 6_ _ _ = 1976; 6163 = 163 days after 1 Nov 75.
[2] Standard error.
[3] Chemical analysis not conducted.

APPENDIX M

AVERAGE (N=25) CHEMICAL YIELD (KG/HA, $\bar{X}$±SE) IN ABOVEGROUND VEGETATION COMPONENTS ON A TALLGRASS PRAIRIE WATERSHED GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-78

TABLE M-1. AVERAGE (25 SAMPLES/DAY) NITROGEN YIELD (KG/HA) IN ABOVEGROUND VEGETATION COMPONENTS ON A TALLGRASS PRAIRIE GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-1978

	Live		Standing Dead		Ground Litter		Total	
DAY[1]	$\bar{X}$	SE[2]	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
6163	14.5	2.3	10.5	1.8	7.3	1.1	32.3	4.4
6183	27.4	4.4	10.9	2.6	12.0	0.8	51.2	5.9
6206	28.0	5.0	1.23	1.6	23.2	2.5	63.5	5.1
6234	37.5	11.6	10.6	1.3	21.0	1.7	69.0	11.3
6262	33.5	5.9	9.7	0.9	12.2	1.0	55.4	6.0
6290	32.9	5.6	9.9	1.1	14.3	1.4	57.0	6.4
6320	42.2	12.6	11.5	1.4	13.9	2.2	67.5	13.0
6346	26.1	5.7	23.3	2.2	--[3]	--	49.4	6.9
7010	27.2	6.7	18.6	2.3	--	--	45.7	6.7
7040	31.7	7.4	13.2	1.7	--	--	45.4	8.1
7090	22.3	3.0	16.6	2.1	--	--	38.9	3.5
7130	17.9	3.1	8.5	2.0	--	--	26.3	3.4
7160	--	--	12.5	1.9	--	--		
7192	--	--	11.1	1.9	21.5	2.2		
7220	--	--	5.6	1.2	17.5	1.2		
7250	--	--	6.0	0.5	13.8	1.1		
7275	--	--	--	--	--	--		
7312	--	--	7.1	0.8	15.0	1.8		
7347	--	--	15.5	1.4	--	--		
8017	--	--	11.0	1.4	--	--		
8050	--	--	8.8	0.8	--	--		
8120	--	--	10.5	1.5	--	--		
8148	--	--	7.1	0.8	--	--		
8176	--	--	6.1	1.1	9.0	0.8		
8205	--	--	7.0	1.0	13.1	0.9		
8233	--	--	7.6	0.8	17.7	1.4		
8254	--	--	6.8	0.5	16.5	1.6		
8290	--	--	7.5	0.6	17.2	1.2		
8317	--	--	--	--	8.7	0.8		
8343	--	--	10.4	1.2	8.0	1.5		

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[1] Plant year date: 6_ _ _ = 1976; 6163 = 163 days after 1 Nov 75.

[2] Standard error.

[3] Chemical analysis not conducted; Live included in Standing Dead 6346-7160 and 7347-8148.

TABLE M-2. AVERAGE (25 SAMPLES/DAY) PHOSPHORUS YIELD (KG/HA) IN ABOVE-GROUND VEGETATION COMPONENTS ON A TALLGRASS PRAIRIE GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-1978

	Live		Standing Dead		Ground Litter		Total	
DAY[1]	$\bar{X}$	SE[2]	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
6163	0.92	0.15	0.57	0.10	0.55	0.08	2.04	0.26
6183	2.54	0.67	0.59	0.10	0.99	0.07	4.21	0.74
6206	1.97	0.51	0.58	0.07	1.44	0.17	4.00	0.50
6234	3.08	1.03	0.44	0.06	0.95	0.06	4.46	1.02
6262	1.96	0.41	0.43	0.05	0.68	0.05	3.07	0.42
6290	1.99	0.36	0.53	0.06	0.92	0.08	3.33	0.44
6320	2.69	0.97	0.57	0.07	0.85	0.13	4.12	0.98
6346	1.71	0.58	1.18	0.11	- [3]	-	2.89	0.64
7010	1.45	0.30	0.92	0.14	-	-	2.37	0.32
7040	1.68	0.39	0.56	0.08	-	-	2.30	0.44
7090	1.93	0.32	0.62	0.10	-	-	2.55	0.35
7130	1.07	0.24	0.43	0.10	-	-	1.50	0.24
7160	-	-	0.92	0.20	-	-		
7192	-	-	0.35	0.07	1.04	0.09		
7220	-	-	0.27	0.05	1.36	0.13		
7250	-	-	0.29	0.04	0.82	0.06		
7275	-	-	-	-	-	-	-	-
7312	-	-	0.32	0.04	1.06	0.13		
7347	-	-	1.12	0.14	-	-		
8017	-	-	1.21	0.19	-	-		
8050	-	-	0.47	0.05	-	-		
8120	-	-	0.40	0.06	-	-		
8148	-	-	0.40	0.07	-	-		
8176	-	-	0.36	0.07	0.86	0.10		
8205	-	-	0.52	0.09	1.02	0.12		
8233	-	-	0.54	0.11	1.33	0.09		
8254	-	-	0.41	0.04	1.28	0.12		
8290	-	-	0.42	0.04	1.42	0.11		
8317	-	-	-	-	0.73	0.08		
8343	-	-	0.78	0.09	1.37	0.54		

[1] Plant year date: 6___ = 1976; 6163 = 163 days after 1 Nov 75.
[2] Standard error.
[3] Chemical analysis not conducted; Live included in Standing Dead 6346-7160 and 7347-8148.

TABLE M-3. AVERAGE (25 SAMPLES/DAY) POTASSIUM YIELD (KG/HA) IN ABOVEGROUND VEGETATION COMPONENTS ON A TALLGRASS PRAIRIE GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-1978

	Live		Standing Dead		Ground Litter		Total	
DAY[1]	$\bar{X}$	SE[2]	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
6163	8.3	1.4	6.2	1.2	1.5	0.2	16.0	2.3
6183	5.6	0.9	1.7	0.3	10.0	0.7	17.4	1.4
6206	5.4	0.9	2.3	0.3	17.7	1.9	25.4	2.0
6234	6.4	1.4	3.4	0.4	17.5	1.3	27.2	1.9
6262	5.5	0.7	3.1	0.3	10.0	0.7	18.6	1.1
6290	5.3	0.8	2.9	0.3	13.8	1.2	21.3	1.7
6320	7.4	2.2	4.2	0.6	11.4	1.7	23.0	3.1
6346	4.9	1.2	10.0	1.0	- [3]	-	14.9	1.8
7010	5.7	1.0	7.3	0.9	-	-	13.0	1.4
7040	7.3	1.7	3.2	0.4	-	-	10.6	1.9
7090	4.6	0.5	2.6	0.5	-	-	7.2	0.7
7130	4.1	1.0	1.2	0.3	-	-	5.3	1.0
7160	-	-	4.9	0.9	-	-		
7192	-	-	2.7	0.6	15.4	1.0		
7220	-	-	2.6	0.4	19.7	1.9		
7250	-	-	3.1	0.4	13.4	0.9		
7275	-	-	-	-	-	-		
7312	-	-	4.4	0.5	16.4	1.9	-	-
7347	-	-	11.2	1.1				
8017	-	-	5.5	0.8	-	-		
8050	-	-	2.6	0.3	-	-		
8120	-	-	1.4	0.3	-	-		
8148	-	-	1.9	0.4	-	-		
8176	-	-	8.7	2.3	10.0	0.9		
8205	-	-	2.8	0.4	15.8	1.3		
8233	-	-	3.0	0.5	24.2	2.0		
8254	-	-	5.1	0.4	24.8	2.4		
8290	-	-	3.0	0.4	22.9	1.8		
8317	-	-	-	-	11.2	1.2		
8343	-	-	2.9	0.3	8.9	1.6		

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[1] Plant year date: 6___ = 1976; 6163 = 163 days after 1 Nov 75.

[2] Standard error.

[3] Chemical analysis not conducted; Live included in Standing Dead 6346-7160 and 7347-8148.

TABLE M-4. AVERAGE (25 SAMPLES/DAY) CALCIUM YIELD (KG/HA) IN ABOVE-GROUND VEGETATION COMPONENTS ON A TALLGRASS PRAIRIE GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-1978

	Live		Standing Dead		Ground Litter		Total	
DAY[1]	$\bar{X}$	SE[2]	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
6163	8.3	1.4	6.2	1.2	1.5	0.2	16.0	2.3
6183	15.4	2.6	6.3	1.2	3.6	0.3	25.7	3.3
6206	17.9	3.7	6.0	0.7	7.4	1.0	31.2	3.7
6234	21.2	6.2	5.4	0.7	7.2	0.7	33.8	6.0
6262	16.9	2.9	6.3	0.7	4.3	0.4	27.6	3.1
6290	20.1	3.8	6.0	0.6	6.8	0.9	30.5	3.9
6320	29.1	10.9	6.6	0.8	6.2	1.3	42.9	11.2
6346	13.1	2.8	8.6	0.9	-[3]	-	21.7	3.4
7010	14.9	5.2	9.5	1.2	-	-	24.5	5.2
7040	13.5	2.4	7.8	1.1	-	-	20.8	2.9
7090	8.6	1.4	8.2	1.2	-	-	16.8	1.9
7130	10.8	2.3	4.5	0.9	-	-	15.3	2.5
7160	-	-	6.7	1.2	-	-		
7192	-	-	4.2	0.8	5.4	0.4		
7220	-	-	3.2	0.5	8.0	0.8		
7250	-	-	3.2	0.2	6.7	0.5		
7275	-	-	-	-	-	-	-	-
7312	-	-	1.8	0.2	9.3	1.7		
7347	-	-	8.3	0.9	-	-		
8017	-	-	6.4	0.8	-	-		
8050	-	-	6.3	0.5	-	-		
8120	-	-	5.4	0.9	-	-		
8148	-	-	4.3	0.6	-	-		
8176	-	-	3.7	0.9	2.6	0.3		
8205	-	-	3.6	0.5	5.1	0.5		
8233	-	-	4.1	0.4	9.6	1.1		
8254	-	-	4.6	0.3	10.5	1.2		
8290	-	-	5.2	0.5	10.6	1.6		
8317	-	-	-	-	6.1	0.8		
8343	-	-	6.7	0.8	5.4	1.5		

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[1] Plant year date: 6___ = 1976; 6163 = 163 days after 1 Nov 75.

[2] Standard error.

[3] Chemical analysis not conducted; Live included in Standing Dead 6346-7160 and 7347-8148.

TABLE M-5. AVERAGE (25 SAMPLES/DAY) DIGESTIBLE DRY MATTER YIELD (KG/HA) IN ABOVEGROUND VEGETATION COMPONENTS ON A TALLGRASS PRAIRIE GRAZED BY CATTLE IN NORTH CENTRAL OKLAHOMA, 1976-1978

	Live		Standing Dead		Ground Litter		Total	
DAY[1]	X̄	SE[2]	X̄	SE	X̄	SE	X̄	SE
6163		-[3]		-		-		-
6183		-		-		-		-
6206		-		-		-		-
6234		110		26		522		35
6262		128		20		484		41
6290		342		41		662		50
6320		285		38		537		86
6346		684		65		-		-
7010		-		-		-		-
7040		-		-		-		-
7090		-		-		-		-
7130		-		-		-		-
7160		321		46		-		-
7192		255		35		-		-
7220		209		34		443		28
7250		152		18		674		46
7275		232		35		606		40
7312		208		22		489		53
7347		788		63		513		62
8017		342		47		-		-
8050		235		35		-		-
8120		313		45		-		-
8148		221		26		-		-
8176		247		44		-		-
8205		209		29		256		25
8233		229		30		442		30
8254		269		17		650		46
8290		305		33		744		60
8317		-		-		911		93
8343		-		-		576		53
						262		61

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[1] Plant year date: 6___ = 1976; 6163 = 163 days after 1 Nov 75.

[2] Standard error.

[3] Chemical analysis not conducted; Live included in Standing Dead 6346-7160 and 7347-8148.